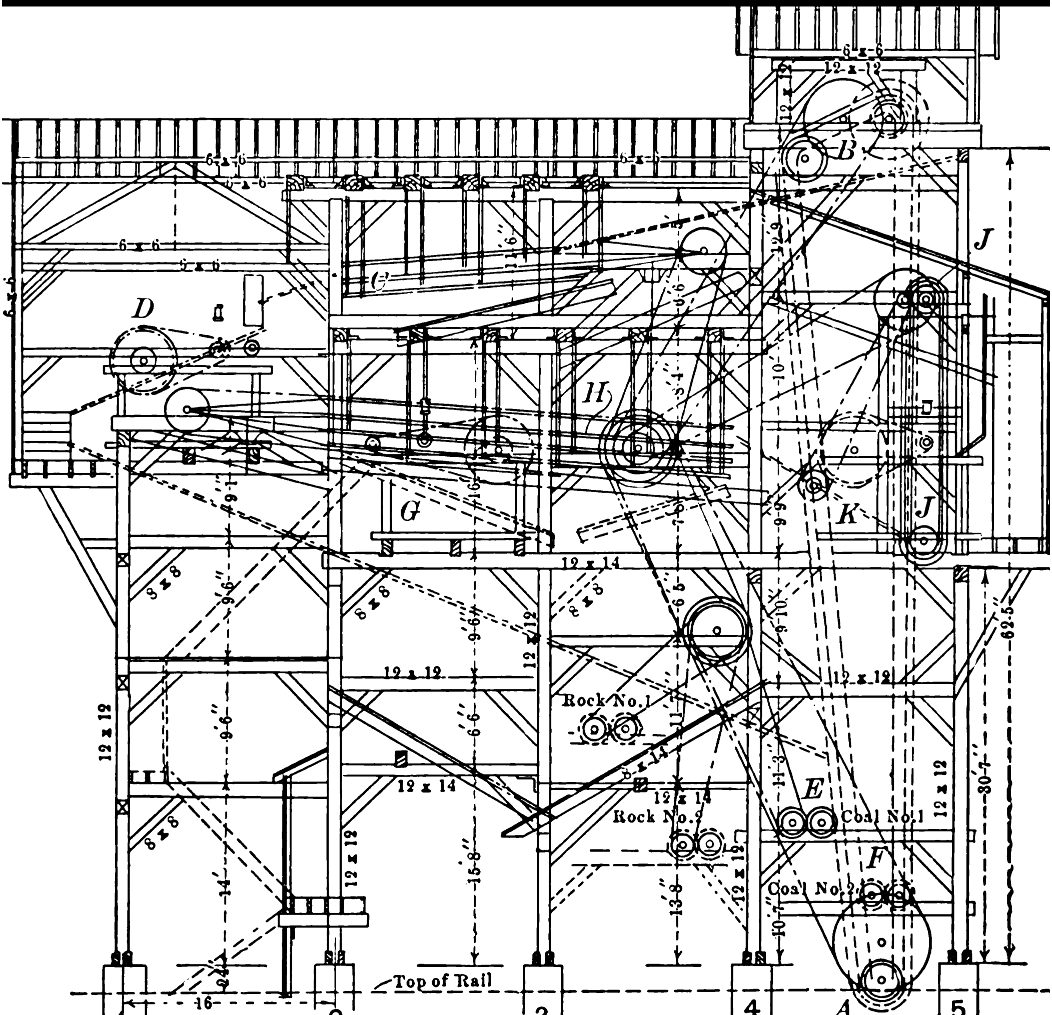

Mining and metallurgy

American Institute of Mining,
Metallurgical, and Petroleum Engineers

Cleveland H. Dodge

No. 6. NOVEMBER. 1905.

Bi-Monthly Bulletin

OF THE

American Institute of Mining Engineers.

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SECTION I.

INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions.*

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BI-MONTHLY BULLETIN.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

All communications concerning the contents of this Bulletin should be addressed to R. W. Raymond, Secretary, 99 John St., New York City (P. O. Box 223; Telephone number 5477 John).

LIBRARY.

The following volumes are needed to complete sets in the library:

Berg- und Hüttenmännische Zeitung, volumes i. to xxi., inclusive.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, *Transactions*, volumes xxiii. to xxvi., inclusive.

Stahl und Eisen, Nos. 1, 2, 3 and 4 of vol. i.; Nos. 8, 9, 11 and 12 of vol. ii.; and indexes of vols. i., ii. and iii.

Zeitschrift für Angewandte Chemie, Years i. to xvii.

Giesserei Zeitung, Year i., Nos. 1 to 17, 19–26; Year ii., Nos. 1 to 6, inclusive.

Accessions.

From August 29 to October 15, 1905.

American Electrochemical Society, Philadelphia.

AMERICAN ELECTROCHEMICAL SOCIETY. *Transactions.* Vol. vii. 8vo. Philadelphia, 1905.

American Institute of Electrical Engineers, New York.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. *Directory of Membership.* 1905. nar. 16mo.

——— *Transactions.* Vols. xxii. and xxiii. 8vo. New York, 1904 and 1905.

American Society of Civil Engineers, New York.

AMERICAN SOCIETY OF CIVIL ENGINEERS. *Transactions.* Vol. liv. 8vo. New York, 1905.

American Society for Testing Materials, Philadelphia.

AMERICAN SOCIETY FOR TESTING MATERIALS. *Proposed Standard Specifications for Cast-Iron Car-Wheels*, 6 p.; *For Gray Iron Castings*, 4 p.; *For Steel Axels*, 3 p.; *For Steel Castings*, 3 p.; *For Steel Forgings*, 4 p.

Atchison, Topeka and Santa Fe Railway Company.

ATCHISON, TOPEKA AND SANTA FE RAILWAY COMPANY. *Tenth Annual Report.* 1905. 8vo.

L. E. Aubury.

CALIFORNIA STATE MINING BUREAU. *Gold Dredging in California*, by J. E. Doolittle. 120 p. il. pl. maps. 8vo. Sacramento, 1905. (Bulletin No. 36.)

——— *Gems, Jewellers' Materials, and Ornamental Stones of California*, by G. F. Kunz. 171 p. il. pl. 8vo. Sacramento, 1905. (Bulletin No. 37.)

Bureau of Geology and Mines, Rolla, Mo.

MISSOURI BUREAU OF GEOLOGY AND MINES. (*The*) *Geology of Moniteau County*, by F. B. Van Horn, with an Introduction by E. R. Buckley. viii, [1], 104 p. pl. map. 8vo. Jefferson City, 1905. (Vol. iii., 2d Series.)

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RHODESIA CHAMBER OF MINES. *Tenth Annual Report.* 4to. Bulawayo, 1905.

Colorado Iron Works Company, Denver.

COLORADO IRON WORKS COMPANY. *Some Details as to Smelting Practice.* 157 p. il. 8vo. Denver, 1905.

C. D. Demond.

THORP, F. H. *Outlines of Industrial Chemistry.* Edition 2, revised and enlarged, and including a chapter on Metallurgy by C. D. Demond. xxx, 618 p. il. 8vo. New York, 1905.

Department of Commerce and Labor—Bureau of Standards.

U. S. BUREAU OF STANDARDS. *Laws Concerning the Weights and Measures of the United States.* Compiled by L. A. Fischer and H. D. Hubbard. ix, 476 p. 4to. Washington, 1905.

Vve. Ch. Dunod.

LA GOUPILLIÈRE, HATON DE. *Cours D'Exploitation des Mines.* Edition 3. Revue et Augmentée par Jean Bès de Berg. (2 vols.) vol. i., il. 8vo. Paris, 1905.

[SECRETARY'S NOTE.—The third edition of the comprehensive work of the famous Director of the *École des Mines*, brought up to date by a competent hand, and now constituting the latest summary of the art of mining. It does not include economic geology, but is all the more comprehensive and complete in the various branches of mining proper. This first volume deals with the discovery, exploration, and re-discovery (after interruption by faults) of mineral deposits; methods and uses of boring; various methods of excavation; explosives; machine-drills and cutters; shafts and levels; timbering; masonry and metallic props; tunneling; shaft-sinking in dry or wet ground; through quicksands, etc. It comprises 1,000 octavo pages, beautifully printed, with numerous illustrations.—R. W. R.]

Engineers' School, United States Army, Washington.

U. S.—ENGINEERS' SCHOOL. *Improved Methods of Building Construction.* Being a Lecture Delivered by Captain J. S. Sewell. 19 p. 8vo. Washington, 1905.

Engineering and Mining Journal.

One Hundred and Forty-Five Odd Numbers of Periodicals.

POORE, P. B. *Descriptive Catalogue of the United States Government Publications*, 1774–1881. iv, 1392 p. 4to. Washington, 1885.

RICKARD, T. A. Editor. *Pyrite Smelting.* 310 p. 8vo. New York, 1905.

[SECRETARY'S NOTE.—A reprint of many contributions to the *Engineering and Mining Journal*, revised by their authors, and accompanied with a critical introduction by Mr. T. A. Rickard, the Editor, and an admirable review of the discussion and the general subject, by Dr. Edward D. Peters, constituting an invaluable aid to the student or practitioner in one of the most important, yet (in standard text-books) most inadequately treated, departments of modern metallurgy.—R. W. R.]

Erie Railroad Company.

ERIE RAILROAD COMPANY. *Tenth Annual Report of the Board of Directors.* 1905. 4to. New York, 1905.

A. Faber du Faur.

HARTMANN, CARL. *Conversation Lexikon der Berg,-Hütten-und Salzwerkskunde.* . . . 4 vols. 12mo. Stuttgart, 1840–'41.

KARSTEN, C. J. B. *Handbuch der Eisenhüttenkunde.* Vols. i–iv and atlas. Edition 3. 8vo. Atlas f°. Berlin, 1841.
Wanting vol. v.

——— *System der Metallurgie.* 5 vols. and atlas. 8vo. Berlin, 1831.

VALERIUS, B. *Fabrication du fer.* 360 p. 8vo. Paris, 1854.

——— Atlas. 4to.

WOLLUNDER, C. F. *Tagebuch einer metallurgisch, technologischen Reise, durch Mahren, Böhmen, einen Theil von Deutschland und der Niederlande.* xvi, 487 p. 12mo. Nürnberg, 1824.

Sydney Fawns.

FAWNS, SYDNEY. *Tin Deposits of the World.* xii., 240 p. 8vo. London, 1905.

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ALDEN, W. C. *Delavan Lode of the Lake Michigan Glacier of the Wisconsin Stage of Glaciation and Associated Phenomena.* 106 p. pl. maps. 4to. Washington, 1904. (U. S. Geological Survey. Professional Paper No. 34.)

BAIN, H. F. and ULRICH, E. O. *Copper Deposits of Missouri.* 52 p. il. pl. 8vo. Washington, 1905. (U. S. Geological Survey. Bulletin No. 267.)

BOUTWELL, J. M. *Economic Geology of the Bingham Mining District, Utah, with a Section on Areal Geology* by Arthur Keith and an Introduction on General Geology by S. F. Emmons. 413 p. pl. map. 4to. Washington, 1905. (U. S. Geological Survey. Professional Paper No. 38.)

MENDENHALL, W. C. *Geology of the Central Copper Region, Alaska.* 133 p. il. p. maps. 4to. Washington, 1905. (U. S. Geological Survey. Professional Paper No. 41.)

PRINDLE, L. M. *Gold Placers of the Fortymile, Birch Creek and Fairbanks Regions, Alaska.* 89, xi p. pl. maps. 8vo. Washington, 1905. (U. S. Geological Survey. Bulletin No. 251.)

SPURR, J. E. *Geology of the Tonopah District, Nevada.* 295 p. il. pl. map. 4to. Washington, 1905. (U. S. Geological Survey. Professional Paper No. 42.)

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C. B. Horwood.

HORWOOD, C. B. *The Dolomite Formation of the Transvaal.* 18, [1] p. pl. 8vo. Johannesburg, 1905.

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INSTITUTION OF MINING AND METALLURGY. Bulletin Nos. 12–13. 12mo. London, 1905.

CROSLEY, WILLIAM. *The Computation of Assay Values.* 13 p. il. 8vo. London, 1905.

——— *A Graphic Calculator.* 6 p. il. 8vo. London, 1905.

DIETSCH, F. *Treatment of Tin Wolfram Copper Ores at the Clitter's United Mines.* 27 p. il. 8vo. London, 1905.

WAY, E. J. *Ore Valuation of a Witwatersrand Mine.* 3 p. 8vo. London, 1905.

Iron and Steel Institute, London.

IRON AND STEEL INSTITUTE. *Journal.* Vol. lxvii. 8vo. London, 1905.

Junior Institution of Engineers, London.

JUNIOR INSTITUTION OF ENGINEERS. *Records of Transactions.* Vol. xiv. 8vo. London, 1905.

Liverpool Engineering Society.

LIVERPOOL ENGINEERING SOCIETY. *Transactions.* Vol. xxvi. 8vo. Liverpool, 1905.

David Levat.

LEVAT, D. *Industrie l'aurifère.* 920 p. 8vo. Paris, 1905.

[SECRETARY'S NOTE.—A handsomely printed and illustrated compilation of science and practice concerning the nature, properties, uses and production of gold. The best review of it is its own table of contents, which comprises: an introduction, discussing the extent, causes and characteristics of the progress of the world's production of gold, and a general statement of the properties and metallurgy of the metal; an elaborate account of the characteristics and methods of exploitation of placer-gold deposits in various countries; auriferous veins, and the treatment of their contents by amalgamation, concentration, chlorination, cyanidation, etc. Finally (perhaps most important of all) there is a series of separate articles, describing typical plants and methods at the Treadwell mine, Douglas Island, Alaska; the Homestake and the Maitland mines, So. Dak.; the Camp Bird mine, Colo.; chlorination in Cripple Creek, Colo., and in South Carolina; decantation at the Crown Deep mine in the Transvaal; dry-crushing at Kalgoorlie, West Australia, and Hauraki, New Zealand; and bromo-cyanidation at Hannan's Star mine, West Australia. Interesting statistics of the past, present and probable future production of gold, and a general review of the world's chief producing districts, with an alphabetical index, conclude the volume.—R. W. R.]

A. H. Low.

Low, A. H. *Technical Methods of Ore Analysis.* x, 273 p. 8vo. New York, 1905.

[SECRETARY'S NOTE.—A clear, well-arranged, and up-to-date manual for the guidance of technical chemists and assayers, especially in dealing with problems outside of the daily routine with which each, in his professional practice, has become familiar. Methods are given for the determination of many metals, and for the examination of boiler-waters, coals and cokes, crude petroleum, etc., together with useful tables.—R. W. R.]

New York State Library.

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New Zealand Institute, Wellington.

NEW ZEALAND INSTITUTE. *Transactions and Proceedings.* Vol. xxxviii. 8vo. Wellington, 1905.

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Professor G. H. Perkins.

VERMONT GEOLOGICAL SURVEY. *Report of the State Geologist,* 1903–'04. 8vo. Montpelier, 1904.

R. W. Raymond.

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CONNECTICUT—GEOLOGICAL AND NATURAL HISTORY SURVEY. *The Clay and Clay Industries of Connecticut,* by G. F. Loughlin. 121 p. il. pl. map. 8vo. Hartford, 1905. (Bulletin No. 4.)

Arthur Thacher.

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Compressed Air. Vol. i, Nos. 1, 3–6; vol. ii, Nos. 1, 4–11; Index to vol. iii; vol. iv, No. 3. 8vo. New York.

PURCHASES.

Canadian Mining Manual. Vol. xiv. 8vo. Montreal, 1905.

INTERNATIONAL BUREAU OF AMERICAN REPUBLICS. *Argentine Republic.* 976 p. 8vo. Washington, 1903.

——— *Bolivia.* 214 p. 8vo. Washington, 1904.

——— *Honduras.* 252 p. 8vo. Washington, 1904.

JACOBSEN, EMIL. *General Register zum chemisch-technischen Repertorium* (for vols. vi–xxxv). 6 vols. 8vo. Berlin, 1873–'98.

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SECTION II.

TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents, pages i and ii.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Genesis of the Ore-Deposits at Bingham, Utah.*

BY J. M. BOUTWELL, WASHINGTON, D. C.

(Washington Meeting, May, 1905.)

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I. *Introduction.*

THE object of this paper is to present a concise statement on the genesis of the copper- and lead-deposits of the Bingham

* Published by permission of the Director of the U. S. Geological Survey.

Mining District, Utah. It is essentially a condensation of a chapter in a detailed report on this district, together with so much on geologic features, and on the character and occurrence of the ores as bears on the problems of ore-deposition.[1] The studies upon which the paper is based were undertaken in 1900 under the direction of S. F. Emmons, Geologist-in-Charge of the Section of Metalliferous Deposits, U. S. Geological Survey; and a little additional data was secured in subsequent years. The evidence then obtained as to the genesis of the replacement copper-ores has led to conclusions which differ somewhat from explanations hitherto current. Accordingly, it seems desirable briefly to present the facts together with the resulting conclusions in a separate paper.

II. *General Geography.*

The Bingham district is the leading copper-producing camp in Utah. It is situated in the north central part of the State (Lat. 112° 9′ N., Long. 40° 32′ W.) in the Oquirrh mountains, 20 miles southwest of Salt Lake City. The main slopes of the Oquirrhs, rising steeply from elevations of about 5,000 ft. on the surrounding desert to elevations of 10,000 ft. on the main divide, are deeply dissected by many narrow, steep-walled canyons. Toward the northern end of the range a prominent canyon follows a crescentic course northeastward across its eastern slope and receives several tributary canyons from the west. This is Bingham canyon, which has given the name to the mining-district, and its drainage-basin embraces the principal mining-localities which constitute the Bingham district.

This district extends from the Jordan valley on the east across the eastern slope of the range and the main divide, and well down the western slope. The productive region proper, occupied by about 125 properties, embraces an area of about 15 sq. miles; and the five great properties which produce the bulk of the present output lie within a single square mile. Bingham canyon with its tributaries drains the central and more important portions. The slopes present a very rugged,

[1] The complete report, Professional Paper No. 38, with maps, sections and illustrations, may be obtained free upon request to the Director U. S. Geological Survey, Washington, D. C.

scantily vegetated surface that rises precipitously from narrow partly-graded bottoms to steep ledgy divides.

Bingham precinct, including the principal settlement scattered along the bottom of Lower Bingham canyon and several smaller settlements which have grown up about the larger mines, has a population of about 2,000 (1,872, Census of 1900). Railroad connection with the trunk-line of the Rio Grande Western Railroad at Bingham Junction (11 miles south of Salt Lake City) is by a branch line 14 miles in length.

The region as a whole is poorly watered. In this immediate

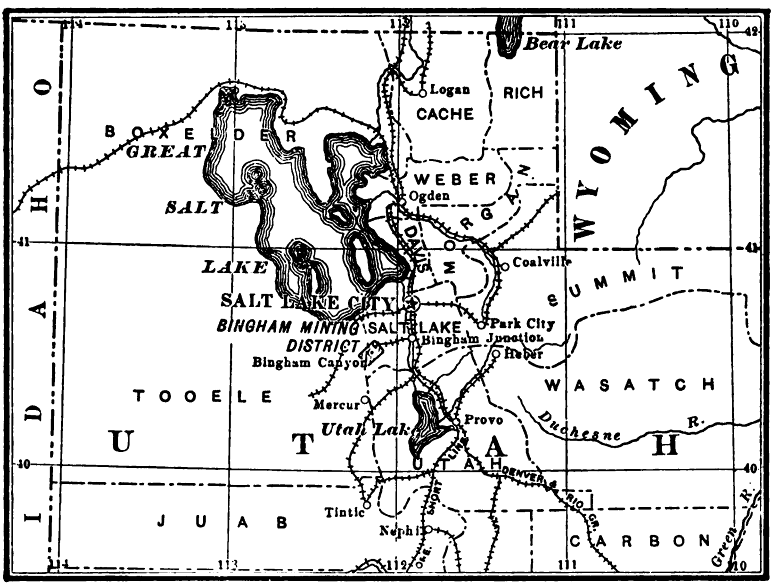

FIG. 1.—MAP SHOWING SITUATION OF THE BINGHAM MINING DISTRICT.

section only the main canyons and their larger tributaries carry water. A few good springs are known, though in the vicinity of the mining-regions the main sources of water-supply are subterranean courses tapped by underground workings.

Vegetation is relatively sparse. Sagebrush (*artemisia*) is the prevailing growth on the lower slopes adjoining the deserts. Scrub oak with an occasional cactus plant (*puntia vulgaris*), juniper, spruces and some pine characterize the middle elevations; and mountain mahogany, certain grasses, and Alpine varieties of wild flowers alone inhabit the higher peaks.

The present topography of the Bingham region is composite.

It indicates that it has been produced during several distinct periods. The prevailing areas are fairly-graded middle slopes or uplands. Above them rise ledgy ungraded peaks along the main divides; and below, these middle slopes fall off abruptly by precipitous cliffs to narrow partly-graded canyons. The present bottoms of these canyons frequently lie upon gravel deposits from 50 to 200 ft. thick. As a whole this region presents a rugged mountainous topography of strong relief.

This district has experienced an unusually varied mining history. It first yielded copper-carbonate ores—the first shipment of ores from Utah being copper-ore from this district—then it attracted attention by its production of placer-gold, amounting in value to about $1,500,000; subsequently it yielded successively carbonate and sulphide lead-ores, oxidized gold-ores, sulphide argentiferous lead-ores, and finally, during the last decade, has gained its present and greatest reputation by its large and increasing production of sulphide copper-ore. The annual output, as reported for 1904, is nearly 1,000,000 tons of ore. The total output is valued at about $40,000,000.

III. *General Geology.*

1. *Sedimentary Rocks.*—The sedimentary section exposed in this district embraces several thousand feet of massive quartzite, thin intercalated limestones, and calcareous shales. The calcareous members have exerted a controlling influence on ore-deposition. This great quartzite section may be broadly divided on lithologic grounds into two parts: a lower which is distinguished by a few comparatively-thin interbedded limestones; and an upper which is distinguished by intercalated black calcareous shales, sandstones and impure limestones.

The age of this succession of sediments is proved by faunas from the limestones, sandstones and shales to be upper Carboniferous (Pennsylvanian).

The sedimentary rocks in this and adjacent districts may be tentatively correlated on paleontologic, lithologic or stratigraphic evidence with part of the general section determined by the geologists of the Fortieth Parallel Survey as the Weber quartzite and Wasatch limestone.

The Bingham series is probably equivalent to a portion of the Weber quartzite.

At Park City, in the Wasatch range, the main quartzite (known locally as the Ontario quartzite) overlies limestones of Wasatch age, and is probably equivalent to the upper portion of the Weber quartzite. At Mercur, a few miles S–SW. of Bingham in the Oquirrh range, the principal ore-bearing horizon is a great blue limestone, in the lower intercalated series, which is considered equivalent to the Wasatch limestone, while the upper intercalated series may be equivalent to the Weber quartzite.[2] At Tintic the chief ore-bearing members are the Eureka and Godiva limestones, which carry lower Carboniferous faunas. At Alta, at the head of Little Cottonwood canyon, the section was examined by the geologists of the Fortieth Parallel Survey, and the limestone, in which most of the important mines of the district are located, was considered as the lower part of the Wasatch limestone.[3] In brief, it appears: (1) that the Wasatch limestone (lower Carboniferous of the Fortieth Parallel Survey) forms the country-rock for the principal ore-bodies at Tintic, Alta and Mercur; (2) that the equivalent of the Weber formation (upper Carboniferous of the Fortieth Parallel Survey) contains the more valuable ore-bodies at Bingham and Park City; (3) that some ore-bearing beds at Park City are of still later age, and thus (4) that the ore-bearing beds of Bingham are equivalent to some of those at Park City, slightly younger than those at Tintic, Alta and Mercur, and older than the youngest at Park City.

2. *Igneous Rocks.*—Igneous rocks of two types occur in this district. One type, which is widely distributed in the forms of dikes, sills, irregular laccoliths and stocks, is intrusive in origin. The other type, which is restricted to the lower portion of the outer (eastern) part of the range and appears to blanket an old land-surface, is extrusive in origin. The various facies of both types exhibit striking lithologic similarity. This fact, together with the absence of distinct cases of rock of one type cutting that of another, makes the determination of their relations somewhat uncertain. It appears, however, that the intrusives and their inclosing sediments were deeply dissected before ex-

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[2] Spurr, J. E. Personal communication to the writer on March 24, 1903.

[3] Emmons, S. F. *Geographical Exploration of the Fortieth Parallel*, vol. ii., p. 364.

trusion occurred; in short, that extrusion followed intrusion at a considerably later period.

The intrusive rocks include two structural types, a fine, dark-gray, even-grained, granular type, and a coarse, porphyritic type. The rocks of the granular type have the general aspect, in hand specimens, of diorite, but on microscopic and chemical study prove to be monzonite. Those of the porphyritic type show in thin section a little free quartz, and appear to carry a sufficiently lower proportion of potash feldspars to render them diorite porphyries, but chemical analysis reveals the presence of sufficient potash in the ground-mass to raise them proportionately high enough for monzonite porphyry. Under the microscope the extrusive rock appears to be hornblende-biotite-andesite. Chemical analysis, however, shows a high percentage of potash, which tends to indicate that this rock belongs to the extrusive type corresponding to monzonite, namely, latite. In brief, these closely related species appear on microscopical and chemical determination to be as follows: The granular intrusive, monzonite; the porphyritic intrusive, monzonite porphyry; and the extrusive, latite.

The extrusives, so far as known, neither carry mineral values themselves nor induce ore-deposition in adjacent country-rock. The intrusives both contain values and induce ore-deposition in the inclosing country-rock.

3. *Areal Geology.*—The general distribution of the sedimentary and igneous rocks is simple, but the detailed distribution is most complex and irregular. Briefly, three limestone series and massive quartzites which separate them occupy the southern and southeastern portions of the area, and strike, from the main divide on the west, northeastward through the district. A great siliceous upper series of quartzites, calcareous shales and sandstones and thin limestones overlie them and occupy the north and northwest half of the area. The intrusives lie mainly in the southern portion of the area in two great divisions, the lower lying south of the middle limestone series (Old Jordan and Commercial limestones) and the upper lying north of and above this series. The sediments and their associated intrusives disappear on the east along a generally N–S. line beneath the later volcanics, which in turn are blanketed by extensive Quaternary deposits.

In the absence of the geological map of this area it may be roughly pictured as follows: Conceive an oblong area in which the four points of the compass lie at the four corners; draw a straight line from the north corner to the middle of the southeast side, and a second line from the same corner to the middle of the southwest side; then the first line will mark the contact between the late deposits (Quaternary and volcanic) on the east and the Carboniferous on the west, and the second will delimit the great siliceous series on the north from the main mineralized area comprising the limestone series with separating quartzites and intrusives on the south.

The fissures continue for many hundred feet along their strike and have not as yet given out in depth. They cut every formation and every kind of rock in the district, and pass continuously from one formation into another.

4. *Structural Geology.*—The area occupied by this district lies in a broad, shallow, synclinal basin, which pitches gently northward. This basin is limited on the west by an anticline and on the east by a steep upturn. Minor folds occur, but they are relatively unimportant.

Fissures as passages for ore-bearing agents and as fault-planes on which ore-bodies have been displaced are the most important features of deformation. Complex and recurrent fissuring, fracturing and crushing, of an intense nature, took place at several periods throughout the district.

The fractures of Bingham vary widely in general character. They range from a net-work of irregular cracks and zones of intense crushing to simple individual fissures and zones of fissures.

The fissures and fractures trend and dip toward all points of the compass. Intersections and comparison of physical features indicate that the fissuring occurred in at least three distinct periods, as follows: in NE–SW. (and N–S.); then in NW–SE., and finally in NE–SW. directions.

The geologic age of the fissuring is not closely limited by the evidence at hand. It appears that the earliest fissuring recognized did not take place before upper Carboniferous time, that some probably occurred in late Tertiary time, and that movements are probably still in progress.

In connection with this extensive and complex fissuring in

localities where the contacts of massive limestone with quartzites, or of shale-members, afford the necessary distinctive datum-planes, important faults and zones of faulting have been found, cutting the country-rock and truncating ore-bodies. Faults with trends, dips and displacements of nearly every conceivable character were studied, but no constant direction of movement was observed. Displacement may be expected in any direction. There is no constant relation between the direction of displacement and the dip or strike of a fault-plane. The amount of displacement proved underground rarely exceeds 150 ft., and except on innumerable minor faults averages between 50 and 100 feet.

IV. *General Character of the Ore-Deposits.*

The Bingham deposits yield ores of copper, lead, silver and gold. The present output is made up almost entirely of copper-sulphide ore, and of comparatively small amounts of argentiferous lead-ore.

The copper-ores are chiefly low-grade sulphides, massive chalcopyrite and pyrite. The grade of these ores is raised, however, by comparatively small amounts of the black copper sulphides, chalcocite and tetrahedrite, and of the oxide, tenorite. Quartz is their principal gangue-mineral. The gold-copper milling ore from monzonite is chiefly composed of chalcopyrite and pyrite with a little bornite and magnetite and a highly siliceous gangue. The argentiferous lead-ores are principally made up of galena, tetrahedrite and zinc blende.

The low-grade sulphide copper-ore occurs as a massive bedded deposit in marbleized limestone. The auriferous copper-ore is found disseminated throughout large masses of monzonite, more particularly, however, in fractured, crushed and altered areas. The argentiferous lead-ores carrying accessory gold and copper with associated zinc are almost entirely restricted to veins and lodes.

Differences in their composition, structure and geologic occurrence, indicative of genetic differences, throw these ores into three distinct classes. The genesis of the Bingham ores may thus be considered under the following heads: Genesis of the Disseminated Ore in Monzonite; Genesis of the Ore in Fissures; Genesis of the Copper-Ore in Limestone.

V. *Genesis of Disseminated Ore in Monzonite.*

1. *General.*—Copper-ore occurs in the igneous rocks of this district in two forms, (1) impregnations of only the immediate walls of normal ore-bearing fissures, and (2) disseminations through extensive masses of altered monzonite. The former is characterized by narrow zones of cupriferous granular and semi-crystalline pyrite which is present most abundantly at fissures, gradually decreases in amount away from them, and fades out within a short distance. This alteration and pyritization of the monzonite immediately adjacent to normal fissures is so clearly incident to the formation of the lodes that its consideration will naturally be taken up in connection with the explanation of the origin of the ore in fissures. The disseminated copper-ore, however, has not been observed to be associated with normal ore-bearing fissures, but appears in certain significant characteristics to form a separate type. The pyrite in the altered monzonite adjacent to ore-bearing fissures is clearly secondary. The immediate problem remaining is then whether the grains of pyrite and chalcopyrite thoroughly disseminated through extensive masses of monzonite entered upon their present state at the time of the igneous invasions or subsequently through secondary agencies.

2. *Character and Occurrence.*—The occurrence of disseminated ore in igneous rock in Bingham which is most thoroughly known and which thus affords the most favorable opportunity for study is in the intrusive body at upper Bingham known as the Bingham laccolith. This irregular mass has been extensively explored by tunnels, test-pits, borings, and shafts, and thoroughly sampled throughout. In a general way this exploration shows that this extensive mass of monzonite carries disseminated throughout its areal extent, so far as known, irregular grains of pyrite and chalcopyrite; that the known mineralized tract is characterized, not by a series or succession of normal fissures, but by innumerable thin, unsystematized parting-planes; that the rock is exceedingly altered by bleaching and silicification, especially in and adjacent to zonal areas of strong shattering; that assays show copper to be lowest at the surface and in old workings; that in relatively firm, unaltered rock the copper-ore lies in flat scales and films on the silicified

walls of cracks, while in areas of great shattering and alteration it occurs abundantly both on quartz-coated cracks and disseminated in the silicified bleached walls. In brief, copper is disseminated at a depth throughout the monzonite and occurs most abundantly in areas of maximum crushing, silicification and alteration.

3. *Genesis.*—The general character and occurrence apparently indicate a relation between quality of ore and degree of opening, alteration and silicification, and suggest that the metallic contents reached their present state through secondary agencies.

Detailed evidence afforded by fresh and altered monzonite, both in hand specimens and in thin sections, tends to confirm this conclusion based on general criteria. In fresh, slightly-parted specimens of monzonite, pyrite and chalcopyrite, if present, occur sparingly within the mass and seem to be almost entirely restricted to parting-planes. Examination of thin sections shows that the chief constituents named, in the order of their predominance, are,—orthoclase, plagioclase, augite, biotite, and a little hornblende and quartz. The biotite, and less abundantly the augite, include numerous grains of a dark-gray metal, which is probably magnetite. (Fig. 2.) In slightly altered monzonite the augite shows incipient alteration on its margins to uralitic hornblende, the biotite appears paler, and the feldspar shows passage into sericite. A specimen of highly altered monzonite has lost the dark color and compact body and shows instead a dull, light-gray color, a slightly porous structure, and abundant quartz in veinlets and in blotches upon the walls of parting-planes. Under the microscope it is seen that the proportion of acid or salic contents, to the ferromagnesian or femic, has greatly increased. Conspicuous areas of granular quartz are numerous, the orthoclase is highly sericitized, and the femic minerals are represented by numerous irregular patches of small individuals or flakes of dense brown biotite. The quartz and sericite are clearly secondary, and though no direct proof of the age of the biotite has been found, it resembles secondary biotite and may be secondary also. Magnetite, excepting occasional grains, has disappeared, and large amounts of chalcopyrite and pyrite are present in the form of rounded grains, chains and veinlets embedded in

secondary quartz, flaky biotite, and sericitized feldspar (Figs. 3 and 4). From the above-stated field observations and from accordant detailed evidence, it would appear that the absence of chalcopyrite and pyrite in unparted, unaltered monzonite, their abundant occurrence on secondary parting-planes, and their intimate association with sericitized feldspar, a biotite of possible secondary origin, and secondary quartz, show that they attained their present state considerably later than the intrusion and are thus of secondary origin.

Although perfect proof can hardly be expected, it seems improbable that they were developed and deposited in their present state without the introduction of additional elements from without the intrusive mass. The observed stages of metasomatic alteration of magnetite, culminating in the occurrence of minute, ill-defined cores of magnetite without secondary sulphides, and finally in the total disappearance of magnetite, indicate one source of the iron of the chalcopyrite and pyrite. Additional iron was doubtless derived from original augite and biotite. Any additional sulphur which may have been required was probably supplied from without, perhaps from sulphurous gases. The immediate source of the copper and gold remains unproved. If any of the pyrite is original, some of each of these other values might have been included as impurities, but the large remainder can hardly be explained, except by subsequent introduction from without.

The demand for sulphur, copper and gold by such subsequent introduction raises a question as to the nature of their carrier. Evidence on this point is found in their occurrence and the probable manner of alteration.

The areas in which this later deposition of metallic sulphides appears to have attained its maximum are characterized by innumerable fractures, joints and other parting-planes of various kinds. They are regions, then, in which the country has been broken and penetrated by minute passage-ways. Further, the ore occurs not as distinct seams or veinlets filling narrow crevices, but as grains disseminated throughout the altered intrusive. Accordingly, it is not improbable that the transporting and altering agent possessed the properties of an aqueous solution.

The probable temperature of these solutions may be deter-

mined by criteria which Lindgren has described. Thus he finds that a narrow rim of calcite or quartz inclosing crystals of pyrite indicates their deposition from hot waters (hydrothermal metasomatism).[4] He gives as additional characteristics of such processes (hydrothermal metasomatism) the development of sericite, "probably the most universal of all minerals forming in altered rocks near fissures,"[5] and the frequently observed relation between the development of sericite and of quartz. Regarding this relation he has observed that

"sericite forms easily and abundantly from orthoclase and microcline (with equal ease from oligoclase, andesine and labradorite), the foils and fibers developing on cleavage-planes and cracks until they invade the whole crystal. The reaction may be chemically expressed as follows, water containing carbon dioxide being the only reagent necessary:

$$3KAlSi_3O_8 + H_2O + CO_2 = KH_2Al_3(SiO_4)_3 + K_2CO_3 + 6SiO_2.$$

"This reaction is accompanied by a considerable reduction of volume, the sericite occupying less than one-half of the original volume of the orthoclase. If SiO_2 separates as quartz, the aggregate volume of the two secondary minerals shows a reduction of 13 per cent. from the volume of the orthoclase. Very often, however, the quartz is carried away in solution, to be deposited in neighboring open spaces."[6]

In the altered, mineralized monzonite at Bingham these criteria were observed. Thus the presence of quartz rims about the grains of pyrite and chalcopyrite is common. Sericitization of feldspars is pronounced (Figs. 3 and 4) and silicification of the country-rock and reduction in its volume are perhaps the most widespread and noticeable features of the alteration. In the light of this evidence, and in view of the requirement that some of the gold, copper and silver should have been derived from without, it seems highly probable that the hydrous solutions were hot. In brief, evidence tends to show that heated hydrous solutions altered the rock-making and metallic minerals constituting the igneous rock, probably introduced copper, gold and sulphur, and at that time, subse-

[4] Lindgren, Waldemar, Gold-Quartz Veins in Nevada City and Grass Valley; *17th Annual Report of the U. S. Geological Survey*, pt. 3, p. 95.

[5] Lindgren, Waldemar, Metasomatic Processes in Fissure-Veins; *Genesis of Ore-Deposits* (1901), A. I. M. E., p. 527.

[6] Lindgren, Waldemar, Metasomatic Processes in Fissure-Veins; *Genesis of Ore-Deposits* (1901), A. I. M. E., p. 528.

quent to the date of intrusion, generated the later metallic minerals, pyrite and chalcopyrite.

4. *Superficial Alteration.*—Recent superficial alteration has followed the deposition of chalcopyrite and pyrite. Pyrite about its periphery and along cracks which traverse these planes may be seen going over to limonite. This fact, as observed in hand specimens of gold-ores, doubtless explains the relative enrichment of gold values proved by assays to exist in the outer or surface portions of test tunnels in these copper- and gold-bearing intrusives. The brilliant tarnish of grains of chalcopyrite indicates a beginning of alteration, and thin rims of a dark grayish-black metal about chalcopyrite observed under the microscope suggest continuance of that process and replacement by black copper-sulphide. Although the illustration fails to bring them out, rims of a blue-black metallic sulphide occur around grains of chalcopyrite in the thin section shown in one of the photo-micrographs. The reason for the decrease in assay-values of copper along certain open and water-bearing fracture-zones is doubtless to be found in the well-known fact that under the action of surface-waters copper suffers rapid alteration and transportation.

5. *Conclusion.*—It appears then that in the disseminated ores in igneous rock the copper-metals were deposited by hydrothermal action subsequent to the date of igneous intrusion, and that these sulphides are now undergoing normal superficial alteration.

VI. *Genesis of the Ores in Fissures.*

1. *Character.*—The ore occurring in fissures in this district is essentially argentiferous lead-ore carrying minor amounts of copper and gold. It is composed in largest part of the sulphide (galena), and also contains small amounts of lead sulphate (anglesite), lead carbonate (cerussite) and lead oxide (massicot). Massive tetrahedrite of the silver-bearing variety (freibergite) is usually an important accessory, and bears considerable amounts of silver and copper. Zinc blende of massive form is the most abundant gangue-mineral, and quartz, calcite, barite and rhodochrosite are occasionally present in small amount. The silver occurs very largely in galena and tetrahedrite. Pyrargyrite and cerargyrite have been reported.

2. *Occurrence.*—Ore occurs here in fissures, as seams between slickensided walls of normal country-rock, as seams frozen to walls, in zones of these single seams between solid country-rock, and in groups of roughly parallel seams traversing zones of crushed and brecciated material. Both the single mineralized fissure, vein, and the group of veins, lode, are common. The type which most frequently bears ore is a simple fissure characterized by a zone of finely comminuted country-rock, averaging from 1 to 4 ft. wide and inclosed between slickensided walls. The veins and lodes traverse rocks of every lithologic type and age in the district. The prevailing trend of the observed lodes is NE–SW. and their prevailing dip is toward the NW. Barren fissures and fractures trend and dip without apparent system toward all points of the compass. As regards the sequence of fracturing and the deposition of lode-ores, it appears that ore-deposition was preceded by fissuring in NE–SW. directions and followed by faulting on NW–SE. planes, and then on NE–SW. planes. In extent, fissures and fractures have been found to continue several hundred feet along their strike and dip. Their mineral contents, though varying and pinching locally, have not been proved to disappear permanently in either direction.

The strong fissures appear to be the most extensive and most highly mineralized. Localization of pay occurs in both dip-fissures or those lying in the normal fissure and fracture-zone and in strike-fissures or those lying between formations or beds. Shoots in the former, however, though doubtless present, have been only roughly determined as such. Lode-ores in strike-fissures occur in definite shoots with decided pitch. The prevailing structure of the lodes is a banding imparted by parallel pay-streaks within a crushed zone and they in turn are made up of several minerals in massive and semi-crystalline form distributed roughly in bands with ill-defined interlacing boundaries. It is not a typical "crusted" or "crustified" structure, though a general sequence of minerals from wall to core is apparent as follows—Sphalerite, tetrahedrite, pyrite and galena, galena and calcite, rhodochrosite and quartz cores.

In brief, the lead-, silver- and copper-minerals which constitute the fissure-ores are systematically arranged in rough bands in pay-streaks in zones of fracturing which persistently tra-

verse every type of country-rock in a generally NE–SW. direction throughout the district.

3. *Deposition.*—The general character of the deposition of the lode-ores is indicated in part by the form of the ore-bodies, by the structure of the pay-streaks, and by the structure of the ore. Thus the absence of typically defined, crustified structure and sharply defined bands and lines of infacing crystals tends to show that the ore cannot be regarded as entirely a deposit formed within pre-existing open spaces. The restriction of these lodes to practically a single system of zones ot strong fracturing, the continuity of the breaks regardless of their contents, the unity of the pay-streaks, and the roughly banded structure, signify that the fractures existed before ore-deposition and offered partially opened spaces, favorable pathways for the mineral-bearing agent, and suitable areas for ore-deposition. The rough banding and regular succession of the minerals composing the deposits point to a corresponding historical succession in their deposition, and the occasional presence of infacing crystals at the core of some pay-streaks tends to show their deposition from solution.

The extreme regularity of the interlacing boundaries, the intergrowth of arms and lobes of pyrite and galena, the presence of galena surrounding and interlacing with semi-crystalline pyrite, the interweaving of sphalerite and galena, and the close structural relation between sphalerite and tetrahedrite, in short, the presence within each band of considerable portions of the other constituents in massive or crystalline form, tends to show that the fissure-ores were not freely deposited from normal aqueous solutions. These features would rather suggest that the deposition took place from a solution either actually of a pasty, semi-viscous character, or rendered so potentially by pressure, in order to allow apparently contemporaneous deposition throughout the open space.

Filling was frequently supplemented by replacement of walls.

4. *Transporting Agent.*—The physical and chemical character of the agent which introduced the fissure-ores is indicated by the character of its deposits and the influence which it exerted upon the wall-rock.

The occurrence of pay-streaks in thin attenuated plates

along very close fissures, the penetration of filamentous crevices by pyrite veinlets and the structure of the pay-streaks, lead to the conclusion that the ores were deposited from a liquid or from some material that possessed the general properties of a liquid. The character and probable derivation of the contents of this liquid, and evidence that it rose from depth, suggest that the temperature of this liquid was high. The chemical character, judging by its effect on limestone, was that of an acid. Chemical and microscopical study of monzonitic wall-rock shows that the alteration produced by these solutions consists of metasomatic alteration of the ferro-magnesian minerals, of chloritization, sericitization and silicification.

In the course of this metasomatism, pyrite, chalcopyrite and pyrrhotite have been developed. This type of alteration resembles in its essential features that which Lindgren has shown to be characteristic of metasomatic processes in fissure-veins, and from the above facts in themselves and in the light of his studies of similar alteration in various districts, it would appear that the alteration was produced by heated aqueous solutions rich in K_2O.

5. *Immediate Causes of Deposition of Lode-Ores.*—The form of a fissure is generally considered to exert an important influence on deposition, on the general principle that irregularity in a fissure resulting in alternately closed and open, or gaping, portions tends to vary the temperature and pressure of solutions and their solvent power. According to this the wider portions of a fissure should be occupied by larger ore-bodies. In several cases in Bingham the ore thinned in descent when the dip changed, so as to make a decided bend or knee in the fracture-zone, and lenses of ore in zones appeared to "form on the flats."

Two chemical factors seem to have exerted a strong influence upon the precipitation of the lode-ores, namely, calcareous composition and carbonaceous contents of wall-rocks. Ore-bodies in fissures are relatively much thicker between limestone than between quartzite and porphyry walls. Thus the same lode is found to expand laterally on passing from quartzite and porphyry into limestone. Many large lodes and many distinct miniature examples in various portions of the camp bear out the fact that calcareous walls strongly induce ore-deposition.

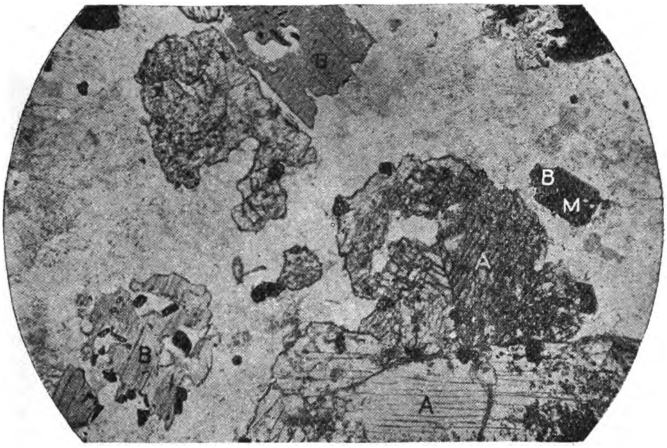

FIG. 2.—TYPICAL MONZONITE OF BINGHAM. (FROM TRIBUNE TUNNEL, TELEGRAPH MINE.) (SP. No. 117 (47). WITH ANALYZER, x 48.)

Fine-grained, granular to subporphyritic structure. Augite (A), biotite (B) and orthoclase form chief constituents. The inclosing areas are almost entirely feldspathic, including both orthoclase and plagioclase, with a little garnet. Augite is slightly uralitized. The small black areas are nearly all magnetite but a few are grains of pyrite.

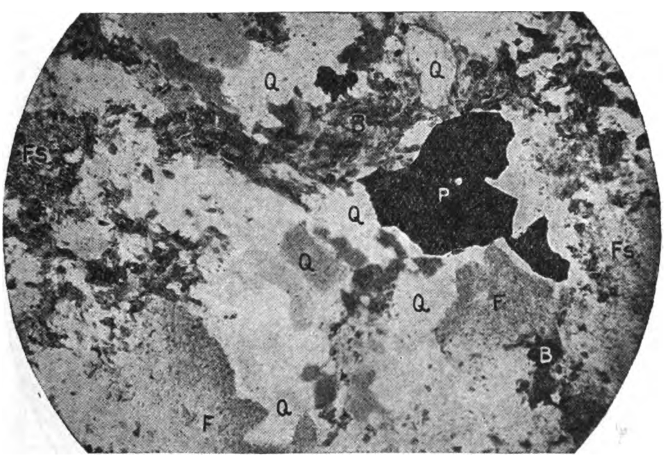

FIG. 3.—DEVELOPMENT OF PYRITE IN ALTERED MONZONITE. (FROM ELDORADO SHAFT, BOSTON CONSOLIDATED GROUP.) (SP. 173 (48D). WITH ANALYZER, x 48.)

Magnetite and original biotite are absent, and pyrite (P) appears embedded in secondary quartz (Q), associated with flocculent aggregates of biotite (B) (probably secondary). Feldspathic constituents have gone over to sericite (F).

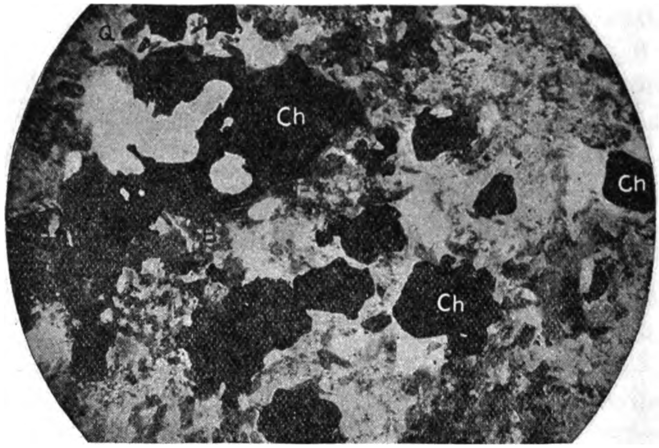

FIG. 4.—CHALCOPYRITE DEVELOPING IN SECONDARY QUARTZ. (SP. NO. 171 (48B). WITH ANALYZER, x 48. FROM DUMP OF ELDORADO SHAFT, BOSTON CONSOLIDATED GROUP.

Magnetite and original biotite individuals have disappeared. Chalcopyrite (Ch) has developed in secondary quartz (Q). Feldspathic groundmass has altered to sericite (S).

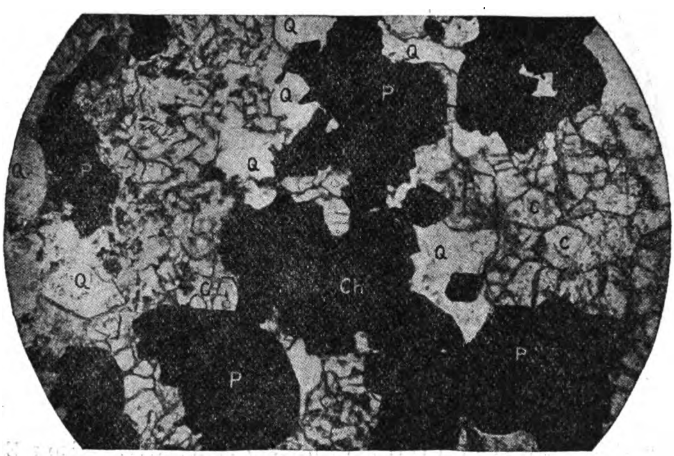

FIG. 5.—CHALCOPYRITE AND PYRITE REPLACING SILICEOUS LIMESTONE. (SP. H. B. 29; WITHOUT ANALYZER, x 66.) FROM NO. 1 ORE-BODY, NO. 6 LEVEL, HIGHLAND BOY MINE.

Irregular intergrowth of chalcopyrite (Ch) and pyrite (P) replacing calcite (C) and quartz (Q).

Fig. 6.—Early Stage in Replacement of Limestone by Copper-Ore. Banded Partially Marmorized Limestone Cut by Strike-Fissures. Highland Boy Mine, No. 6 Level, Looking West. In the walls of these fissures characteristic contact metamorphic minerals appear, and chalcopyrite and specularite replace metamorphic limestone.

FIG. 7.—ADVANCED STAGE IN REPLACEMENT OF LIMESTONE BY COPPER-ORE. TELEGRAPH MINE, GRECIAN BEND LEVEL. The dark bands are chalcocite, chalcopyrite and pyrite, the light ones are granular quartz and cherty siliceous limestone. Retention of bedding-structure indicates replacement.

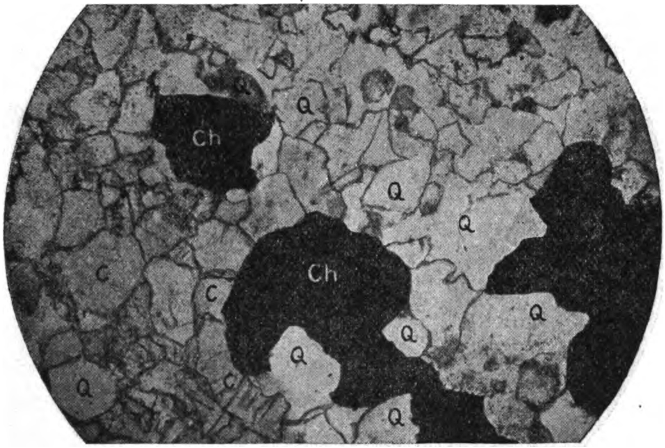

FIG. 8.—CHALCOPYRITE DEVELOPING IN MARMORIZED SILICIFIED LIMESTONE. (SP. H. B. 29; WITHOUT ANALYZER, x 48 +.) FROM NO. 1 ORE-BODY, NO. 6 LEVEL, HIGHLAND BOY MINE.

Chalcopyrite (Ch) invading limestone metamorphosed to siliceous marble made up of granular calcite (C) and quartz (Q). Chalcopyrite replaces calcite and quartz.

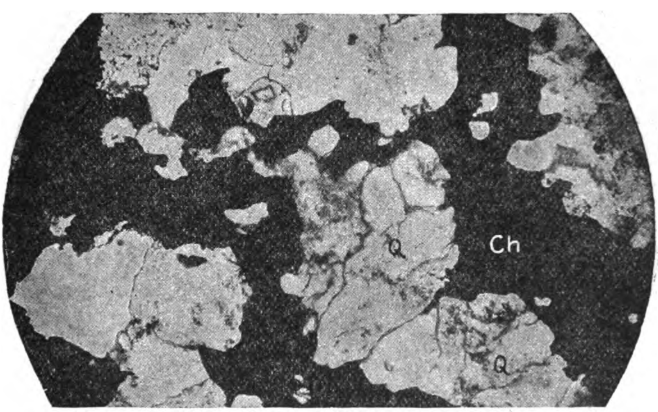

FIG. 9.—INTERGROWTH OF CHALCOPYRITE AND PYRITE REPLACING QUARTZ. (SP. NO. 103b; WITHOUT ANALYZER, x 48.) FROM NO. 4 LEVEL, HIGHLAND BOY MINE.

The chalcopyrite and pyrite (Ch) encircle and replace the quartz (Q) of an entirely silicified limestone. This section from a specimen from an upper level shows evidences of superficial alteration not apparent in the reproduction. The margins of the sulphide are tarnished, showing "peacock" ore.

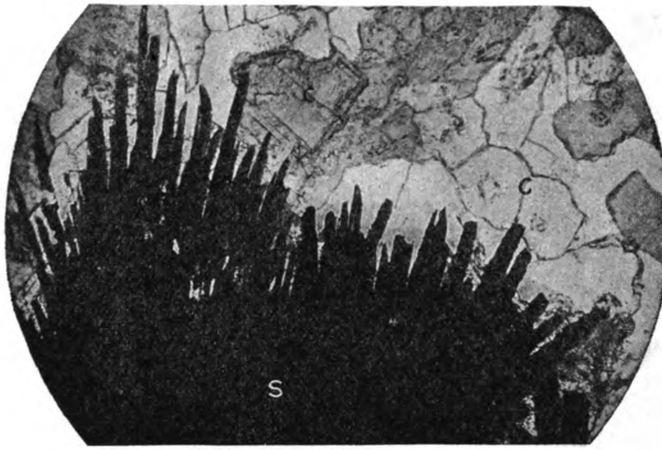

FIG. 10.—SPECULARITE REPLACING CALCITE. (SP. NO. 313; WITHOUT ANALYZER, x 66+.) FROM WALL OF E-W. FISSURE, WEST END NO. 6 LEVEL, HIGHLAND BOY MINE.

The black areas are foils of specularite (S) which replace calcite (C). The hand specimen from which this thin section was made shows chalcopyrite intergrown with specularite and replacing marble.

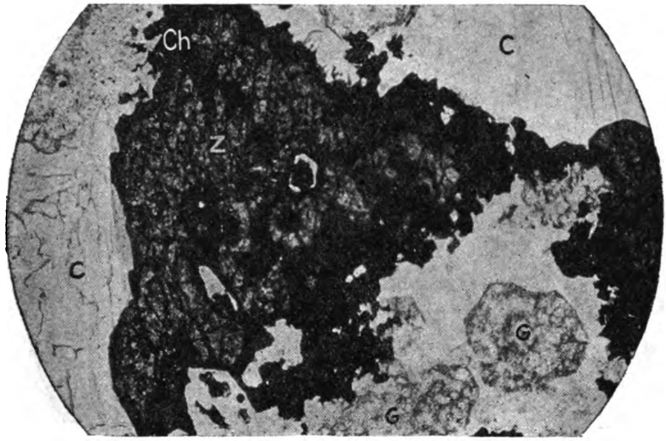

FIG. 11.—CHALCOPYRITE WITH ZINC-BLENDE AND GARNET IN CALCITE. (SP. H. B. 16; WITHOUT ANALYZER, WITH CONVERGER, x 36.) FROM METAMORPHOSED LIMESTONE 60 FT. FROM MONZONITE INTRUSIVE, NO. 7 LEVEL, HIGHLAND BOY MINE.

The darkest areas (Ch) are intergrowths of chalcopyrite and pyrite. They fringe the zinc-blende (Z) and are intergrown with it and green garnet (G). The groundmass is calcite (C).

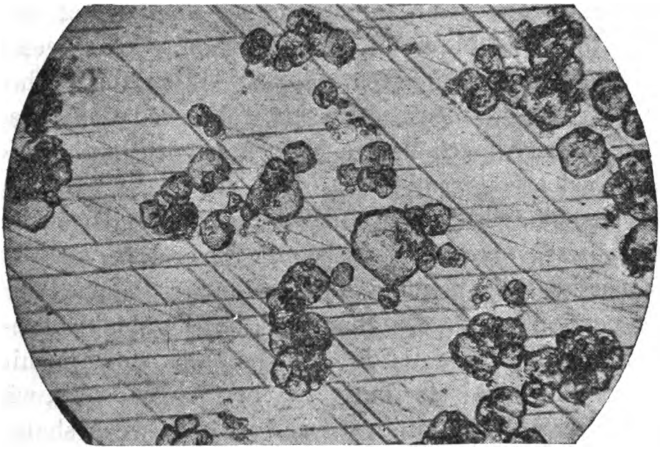

FIG. 12.—GREEN GARNET IN CALCITE. (SP. H. B. 16; WITHOUT ANALYZER, x 36.) FROM HIGHLAND BOY LIMESTONE, NO. 7 LEVEL, HIGHLAND BOY MINE, 60 FT. FROM MONZONITE INTRUSIVE.

Individual crystals and aggregates of crystals of green garnet in marmorized limestone.

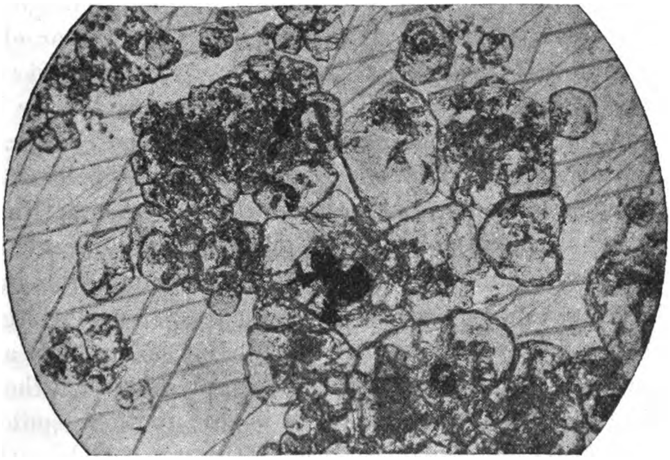

FIG. 13.—CHALCOPYRITE AND PYRITE ASSOCIATED WITH GREEN GARNET IN CALCITE. (SP. H. B. 16; WITHOUT ANALYZER, x 36.)

The darkest areas are chalcopyrite and pyrite grains intergrown with garnet. Near these crystals, just outside of this field, semi-crystalline masses of pyrite and irregular masses of chalcopyrite are developed in and around garnets and zinc-blende.

This factor is so commonly recognized that its extended consideration is unnecessary. The precise character of this influence could not be observed, as the ore-bodies have been so generally removed from the greater lodes. It is probable, however, that it was in large measure like that observed along the minor fissures, namely, metasomatic interchange through which ore replaced calcareous wall-rock.

Black shale, which contained calcareous and carbonaceous matter, also favored ore-deposition. Several fissures cut these thick massive shale-members interbedded in the quartzite in the upper portion of the Bingham section. Valuable ore-bodies occur in them in association with the black shale forming one or both walls. This is illustrated by the Erie vein, which is narrow between quartzite walls and wide between shale walls; thus in passing from quartzite into black shale it changes from a lean seam from 6 to 10 in. wide to a rich shoot 12 ft. wide.

This shale varies from light-gray, dense, thin-bedded, calcareous sandstone to black, fine-grained, massive shale and blue, compact, siliceous limestone. Thin sections of these shales under the microscope are seen to be made up of angular and sub-angular grains of quartz embedded in calcareous and black opaque amorphous matter, and the whole roughly bedded and cut by veinlets of calcite. Chemical analyses of four characteristic samples indicate that these shales are composed chiefly of SiO_2, Al_2O_3 and CaO, and in one instance considerable MgO. The evidence gained through microscopical and chemical examination thus accords in showing the shales to be essentially quartz, calcareous material and amorphous cement. Further, each of these rocks yielded upon analysis some organic material, probably mainly carbonaceous. Accordingly, the brownish-black amorphous matrix, which incloses the quartz grains and imparts to these rocks their dark color, is doubtless aluminous and carbonaceous matter. It would seem then that the precipitating power of these rocks is due to their content of CaO and MgO, together with organic matter mainly carbonaceous. Further, the structure of the rich argentiferous lead-ore in the Erie indicates that the process by which the metals were thus precipitated was replacement.

6. *Superficial Alteration.*—The argentiferous lead-ore in this district has undergone comparatively slight alteration. This

may be largely explained by the fact that galena is relatively stable under oxidizing agencies, and also that quartzite and intrusives which are notably less favorable to oxidation than limestone forms in large measure the country-rock.

Galena occurs on the adit-levels of most of the fissure-mines in a practically unaltered state and may be traced up even through the surface alteration-zone, characterized by "oxidized gold-ore" and carbonate copper-ore, to the present surface. In the early days when the ore immediately below the surface was mined, a small amount of scattered sulphate and carbonate lead-ore appears to have been encountered.

The nature of this alteration is probably exemplified in a sample of silver-lead ore collected from an adit-level. This specimen exhibits five distinct stages of alteration as follows:

(1) The interior core consists of fresh, cleavable galena.

(2) A narrow band, of dull, dark-green to black color on conchoidal fracture, from 0.1 to 0.05 in. wide, marks the periphery of the galena, and extends into it along cracks and pits. On testing this alteration-product chemically it proves to be the lead sulphate, anglesite. It is quite probable that the color is imparted by a trace of copper which, existing as an impurity in the galena, is freed at this first stage of alteration, and then, owing to its ease of alteration, soon passes off. Slight traces of copper, remaining in the form of minute globules of malachite upon the surface, afford some basis for this explanation.

(3) Upon this dark band of sulphate rest thin, grayish-brown lamellæ, which give way to typical gray-brown anglesite in scattered, imperfect crystals with high luster.

(4) The carbonate, as proved by wet tests, occurs upon the surface of this sulphate.

(5) The oxide of lead, in the form of a finely granular, scaly, sulphur-yellow mineral of resinous luster, with streak lighter than color, has formed upon the surface. This may be massicot.

In short, then, the expectable changes resulting through oxidation are here seen in the passage from the sulphide through the sulphate and the carbonate to the oxide.

7. *Conclusion.*—In brief, it appears that heated, aqueous, mineral-bearing solutions rich in CO_2 and K_2O rose along strong NE.–SW. fracture-zones, altered their walls by adding quartz to quartzite, impregnating marble with metallic sulphides and

specularite, and silicifying, sericitizing and impregnating monzonite with metallic sulphides, and deposited the lode-ores in largest volume between calcareous and carbonaceous walls mainly by filling, partly by replacement, and that subsequently these primary sulphide-ores were changed by superficial alteration to sulphates, carbonates and oxides.

VII. *Genesis of the Copper-Ore in Limestone.*

1. *Character.*—These copper-ores, which constitute the bulk of the present output from this district and are thus responsible for its recent growth, have yielded most interesting and valuable data on their genesis. The character of these data, and the fact that they have led to conclusions which differ somewhat from current explanations, are the principal reasons for the preparation of the present paper.

The copper-ore in limestone is a massive pyritic ore composed essentially of sulphides of copper and iron. Chalcopyrite and pyrite form the bulk of the large ore-bodies, and are supplemented by relatively small amounts of chalcocite, tetrahedrite and tenorite. Other copper-bearing minerals found are bornite, binnite, cubanite, enargite, tennantite, bournonite, covellite, cuprite, malachite, azurite, chalcanthite, pisanite and native copper. Quartz predominates in the gangue, and garnet, epidote, tremolite, specularite, pyrrhotite and sphalerite are present in small amounts. These pyritic ores also carry a little gold and silver and an appreciable amount of tellurium. In the enriched black sulphide-ores the amount of tellurium is largely increased, and gold and silver are present in very high values,—probably as tellurides.

2. *Occurrence.*—The large copper-ore bodies are restricted to thick massive limestones which have been subjected to extensive intrusion, intense metamorphism and profound fissuring. The ore occurs adjacent to the intrusives and to the fissures, and is intimately associated with contact-metamorphic minerals. It lies within these metamorphosed limestones along beds at one or more horizons. In form the ore-bodies are irregular lenticular beds, which thicken and thin locally, and terminate laterally along attenuated uneven margins.

In brief, the occurrence of the great copper-bodies, exclusively in those portions of the great limestones that are charac-

terized by pre-mineral fissures, requires that a satisfactory explanation shall recognize this constant and intimate association. And the occurrence of these copper-ores in the vicinity of intrusives within highly metamorphosed limestone in association with tremolite, garnet, epidote, specularite, pyrrhotite, etc., raises the query whether the contact-metamorphism thus indicated may not have also influenced the generation of the copper-ores. One or both of these factors would thus seem to have entered into the formation of this ore, and the explanation of their origin involves a critical examination of the facts with a view to determining the parts probably played by these two genetic processes: (1) deposition from solutions introduced through fissures, and (2) contact-metamorphism.

3. *Deposition.*—A knowledge of the nature of the process aids in determining the cause which led to deposition. The structure of the copper-ore and the occurrence of the ore-minerals afford conclusive evidence as to the process by which the ore was deposited. Evidence on these facts was found in such completeness that its somewhat full presentation seems especially warranted. It comprises the broad structural character of the shoots of copper-ore, the structure of hand specimens of ore, and the occurrence and association of ore-minerals as shown in thin sections under the microscope.

The characteristic broad structure of the copper-ore in limestone is banding. This banding is not like the crustified or even the roughly banded structure of the lodes, but is a bedding which in form is identical with the bedding of the strata. The chief difference is in composition, these beds being composed of ore instead of barren country-rock. Bedded structure characterizes alike miniature ore-bodies, mineralized wall-rock adjacent to seams, and large lenticular ore-shoots. Further, the marked deposition of ore along certain beds and the slight deposition along others appears to indicate a selective tendency on the part of mineral in solution for more soluble beds. This selective action leads to a very irregular periphery. The transition from massive, solid ore is not sharp, but gradual, passing from rich copper sulphide through lean copper-ore, still poorer ore, then merely stained country-rock, to normal barren marble. Although the composition changes from ore to barren country-rock, the structure is persistent, so that a bed of ore is

clearly seen to be a portion of the same bed of country-rock; in other words, the ore has retained the bedded structure of its country-rock.

This may be observed in various stages. Thus, the earliest stages are seen where a small amount of ore has taken the place of metamorphosed limestone adjacent to fissures (Fig. 6); later stages where more and more ore has been deposited along the beds, until the greater part of the country-rock has been turned into ore and the original bedding is preserved by bands of silica (Fig. 7), and at last the final stage in which practically the entire mass is ore, and only occasional irregular bands of granular quartz and an indistinct differentiation of the massive sulphide-ore into beds of somewhat unlike types, indicate on a broad scale a bedded structure. Innumerable occurrences of this character leave no doubt as to the banded structure of the copper-ores.

Such features, especially bedding of ore which corresponds to the stratification of the country-rock, are usually considered to signify that the ore has taken the place of the country-rock by substitution. They are characteristic of known replacement deposits.

The general evidence thus afforded by the broad structure, that the copper-deposits in limestone were formed by replacement, is supported by the detailed facts. Just as the massive beds of ore appear to replace massive beds of rock, so these beds of ore preserve the fine lamination of the country-rock. Thus, a hand specimen shows copper- and lead-ore making in bands in an impure semi-crystalline limestone; narrow seams composed of irregular grains of pyrite and chalcopyrite alternate with other thin layers composed of galena, fine-grained copper sulphide and alteration products of limestone. Such criteria, which may be seen on both large and small scale in the various mines, tend to increase the probability that the process of ore-deposition was one of replacement.

They hardly prove, however, that the metasomatic processes noted were "molecular processes involving simultaneous dissolution and precipitation on the one hand," or "previous dissolution and subsequent precipitation on the other."[7] For "the

[7] Lindgren, Waldemar, Metasomatic Processes in Fissure-Veins; Genesis of Ore-Deposits (1901), A. I. M. E., p. 575.

theory of the substitution of ore for rock is to be accepted only when there is definite evidence of pseudomorphic molecular replacement."[8] And Lindgren has held that the only thorough proof of such molecular replacement is that obtained by microscopic examination of the occurrence of individual ore-making minerals.

Microscopic study of thin sections of Bingham copper-ore affords abundant evidence of progressive stages of replacement of the calcareous country-rock by copper-bearing sulphides. These stages may be clearly made out in the order of their development as follows: (1) Calcareous ground-mass showing small, irregular quartz areas, which are occasionally separate and occasionally associated with small grains and tongues of chalcopyrite; (2) coarse quartz and sulphides penetrating a calcareous ground-mass in small, isolated areas and in larger, irregular patches and sinuous veinlets; (3) complete extinction of calcareous ground-mass through replacement by coarse quartz and sulphides; (4) continued replacement by sulphides to extinction of all except occasional bands and isolated areas of granular quartz. (Figs. 5, 8 and 9.)

The process is thus seen to be characterized by a calcareous, partially calcitized ground-mass, penetrated by irregular areas of intimately associated granular quartz, pyrite and chalcopyrite, in which quartz replaces calcite and grains of pyrite and chalcopyrite gradually grow along irregular margins into and replace grains of calcite and quartz.

In brief, the retention of stratification of the country-rock by banding in copper-shoots and the banded structure of ore tend to show the deposition of copper-ore in limestone by replacement of the country-rock. The growth of secondary quartz, pyrite and chalcopyrite in calcite, as observed under the microscope, indicates that the deposition of copper-sulphide ore in limestone took place by molecular replacement.

4. *Relation of Fissures.*—Replacement of the limestone country-rock by copper-sulphide ore might have been induced in either of the two ways under consideration: (1) by entrance of mineral-laden solutions from fissures, or (2) by metamorphic action due to intrusions. The former possibility is the expla-

[8] Becker, G. F., Discussion of Genesis of Ore-Deposits by Posepny; Genesis of Ore-Deposits (1901), A. I. M. E., p. 204.

nation which is found generally current through the district, as it is held that contemporaneously with deposition of the lead-ore all the copper-ore entered the limestone from the fissures. Certain features might appear, on cursory study, to favor this explanation; other facts tend rather to confirm belief in contact-metamorphism.

The current idea is based upon the fact that the principal copper-bodies are either adjacent to, or apparently cut by, strong mineralized fractures, and upon the belief that the copper-ores are contemporaneous with the fissure-ores. The first point is a recognized fact; yet it is noteworthy that in the large number of occurrences studied, the physical connection of fissure-ore with the copper-shoots was not observed in a single case, and the fissures, with two exceptions, did not appear to be feeders for the copper-bodies. Further, the typical replacement ore in limestone is essentially a copper-ore and the typical lode-ore is essentially a lead-silver ore. Thus the ore of the No. 1 shoot in the Highland Boy mine is a mixture of copper and iron sulphides with associated gold and silver in minor amounts, while the ore from the Silver Shield and Galena lodes is an argentiferous galena with some argentiferous tetrahedrite and a scattering of copper and iron sulphides. These two types of ore, the pyritous copper and the argentiferous lead, so far as known, have not been observed to grade one into the other, but are mineralogically distinct. Finally, as regards the relative date of deposition of these two types of ore, the lode-ore is later than the intrusive, and the replacement ore, in part at least, is probably roughly contemporaneous with intrusion. The bulk of the replacement ore was probably either contemporaneous with intrusion or contemporaneous with the subsequent deposition of the lode-ore from later emanations from the deeper still uncooled portion of the intrusives. Certainly not all of the replacement ore was deposited simultaneously with the lode-ore.

These facts throw much reasonable doubt on the belief that all of the copper-ore was deposited in the limestone from solutions which ascended the lode-fissures. Search for conclusive evidence on certain critical points was unsuccessful. The evidence secured does not lead to the conclusion that strong fissures were the sole sources of the copper-bearing solutions.

5. *Relation of Intrusives.*—Ores formed directly through the agency of intrusives, that is, by contact-metamorphism, are commonly known as "contact-deposits." This phrase has been rather loosely applied to several types of ore-deposits, so that further definition is necessary in order to avoid ambiguity. Instances of two of these uses will suffice: (1) Valuable ore-bodies are known to occur in the lower portion of limestone at or near its contact with underlying quartzite. Such deposits are commonly termed by miners "contact-deposits." (2) Again, useful minerals, which in well-recognized instances constitute ore, are found in sedimentary rocks (especially in calcareous sediments) adjacent to intrusives. Such bodies have also been termed "contact-deposits." In this discussion the term "contact-deposits" will be applied only to ore-deposits occurring in metamorphosed sedimentary rocks (more especially limestone) at or within a short distance of an intrusive in association with typical contact-metamorphic minerals.

That the copper-ores of Bingham are causally related to the intrusives, and were thus generated by contact-metamorphism, is strongly suggested by their character and occurrence. The evidence as to the relations of the copper-ores to the intrusives includes their general distribution, their specific location, and their mineralogical association.

The large copper-deposits, as above noted, are restricted to metamorphosed limestone. It is sufficient for immediate purposes to know that a careful study of this metamorphism, with a view to determining (1) whether it is regional or contact in origin, and (2) its character, has afforded significant conclusions. In brief, it was found that the metamorphism of the limestone shows no relationship to the broad dynamic features of the region, but is co-extensive with the intrusives, and thus is probably directly related to them. The general nature of this metamorphism of the limestone is silicification and marmorization, though its specific character varies greatly. Normal blue limestone is changed entirely to coarsely crystalline marble. In other examples the metamorphic product is banded siliceous marble, with nodules and frequently beds of vari-colored chert. Chemical examination shows that the alteration comprises an increase in silica and magnesia and a decrease in calcium and carbon dioxide, or, in brief, that it is a metasomatism consist-

ing of silicification, dolomitization (?) and a partial decarbonization. The distribution and character of the metamorphism thus shows it to be contact-metamorphism.

Furthermore, thorough examination of the position of the bodies of copper-ore with respect to bodies of intrusive rock reveals a most striking propinquity. The copper-deposits not only lie within contact-metamorphosed limestones, and in the vicinity of intrusives, but they are invariably developed close to the intrusives.

Finally, this general evidence is entirely supported by the detailed evidence afforded by the character and mineralogical association of this ore and its gangue. Certain minerals, through their constant association in known deposits, have come to be recognized as indices to respective types of ore-deposits. "Ore-minerals" characteristic of contact-deposits are, "specularite, magnetite, bornite, chalcopyrite, pyrite, pyrrhotite, and more rarely galena and zinc blende." The gangue contains garnet, wollastonite, epidote, ilvaite, amphibole, pyroxene, quartz and calcite; rarely fluorite and barite. "The characteristic feature is the association of the oxides of iron with sulphides," . . . "and the presence of various silicates of lime, magnesia and iron."[9]

All of these characteristic ore-minerals occur in Bingham associated with bodies of copper-ore in limestone, and a number of the gangue-minerals have been recognized. Specularite was found sparingly in float and plentifully in limestone adjacent to fissures of the great east-west fracture-zone (see Fig. 10). It is a finely cleavable variety that occurs in masses associated with magnetite, chalcopyrite and pyrite, and inclosed by bands of hematite. It also occurs in radiating foils mingled with chalcopyrite and pyrite, replacing calcareous wall-rock adjacent to minor fractures. In other cases it is in seams and crystalline flakes associated with the same minerals, and some galena and carbonates of calcium and magnesium. Small quantities of a magnetic black metallic mineral are intimately associated with specularite. No titanium was detected in this by wet test, and it is believed to be magnetite. Galena is found

[9] Lindgren, Waldemar, Character and Genesis of Certain Ore-Deposits; Genesis of Ore-Deposits (1901), A. I. M. E., p. 717.

with these minerals; also zinc blende; both, however, in subordinate amounts. Pyrrhotite in massive form is disseminated through some of the copper-sulphide ore in intimate association with pyrite and chalcopyrite. Finally, pyrite, and especially chalcopyrite, is associated with these type minerals in lean ore on the margins of ore-bodies adjacent to intrusives in the Highland Boy, and constitutes the bulk of the primary copper-ores.

Thus a sample from the base of No. 1 shoot, No. 7 tunnel, Highland Boy mine, along the zone of transition from ore to barren marble, and adjacent to a cross-cutting sill, affords clear evidence on the association of chalcopyrite and garnet in marmorized limestone adjacent to intrusives. The development of pale brownish-green garnet in a ground-mass of calcite is seen, under the microscope, to proceed from small, rounded grains through larger semi-crystalline grains to well-formed crystals and aggregates of crystals (see Figs. 12 and 13). Intimately associated with these garnets are grains and irregular patches of chalcopyrite. Thus grains of chalcopyrite appear at the core of garnet crystals, scattered through them, distributed along their margins, and also associated in similar unsystematic manner with the aggregates and irregular areas of garnet. Occasionally garnet appears inclosed by chalcopyrite. Clearly some of the garnet was formed after some of the chalcopyrite, and before other portions of chalcopyrite. It cannot be affirmed that some of the garnet and some of the chalcopyrite were not formed at distinct dates by different factors. The observed features tend rather to show, however, that the garnet and chalcopyrite are of contemporaneous origin. Again, zinc blende occurs in irregular masses embedded in the calcite groundmass and fringed and penetrated by narrow irregular bands of chalcopyrite (Fig. 11).

A number of the other characteristic gangue-minerals have been detected. Secondary quartz and calcite are found associated with intrusives throughout the district. Greenish-yellow chlorite (a more unusual contact-mineral)[10] has been recognized in several places, especially in the fractured country adjacent to E–W. fissures in the western portion of the Highland

[10] Harker, A., *Petrology for Students*, 2d ed., 1897, p. 283.

Boy mine. It occurs in elongated lenticular areas associated with calcite, adjacent to a fissure within a shear-zone. Again, bands made up of small, irregular grains of chlorite traverse a granular ground-mass of calcite. Branching seams of chalcopyrite penetrate the chlorite along the contacts of these bands with the ground-mass. Plates of chlorite inclose grains of chalcopyrite in another occurrence. In another slide of a sample from the Highland Boy mine, subangular grains and medium-sized pieces of olivine occur, in some instances apparently passing into serpentine. Tremolite occurs in coarse marble in stellate aggregates of white, acicular crystals. A minute bit of an unproved mineral, somewhat resembling fluorite, was found in the Highland Boy; and large areas made up of bundles of fine, parallel acicular crystals or filaments occurring in marble are probably composed of the silicates that are typical of contact-metamorphism of limestone. Further study would doubtless lead to the discovery of other minerals characteristic of contact-metamorphism.

In brief, limitation of the productive ground in this district to the region of intrusives, extensive metamorphism of the limestone within this area due to contact influences, the restriction of the copper-shoots in limestone to areas of contact-metamorphism, the propinquity of these copper-ore bodies and the intrusive bodies, association of oxides of iron with the sulphides of copper, the content of some gold and silver in the sulphides, and the intimate association of gangue-minerals characteristic of contact-deposits with ore-minerals, clearly indicate a causal relationship between the intrusives and the deposition of the copper-ore.

The development of chalcopyrite in contact-metamorphic garnet, and its association with chlorite, pyrrhotite and specularite, prove that some of the copper-ore in limestone is a "contact-deposit."

It appears that the evidence obtained is insufficient to warrant the assignment of the origin of all the copper-ores in limestone to any single cause. That some of the copper-bearing solutions entered the limestone through the lode-fractures has not been disproved. Some facts show, however, that this was not the sole mode of deposition, and concrete evidence in favor of this process is lacking. Accordingly, settlement of this portion of

the problem awaits conclusive evidence. On the other hand, a portion of the copper-ore has been found without doubt to have been immediately due to intrusives. The evidence is not yet sufficiently complete to prove it, but no facts have yet been found which are against the conclusion that all the copper-ore in limestone was formed through the influence of intrusives.

6. *Superficial Alteration.*—The complete sequence of the stages of alteration of the Bingham copper-ores in limestone was not found in connection with any single deposit. The properties which have been opened from the surface through the several zones of alteration to sulphides below water-level have been abandoned in the older portions or are caved. Each stage, however, was observed in some part of the district and these separate items united afford the complete story.

The facts observed in Bingham show, in general, that carbonates, oxides and native copper occur at the surface; that these pass into secondary sulphides, which in turn give way to primary sulphides in depth. Thus, the surface portions of shoots of copper-iron ore in the large mines were made up of malachite and azurite and occasionally contained cuprite. These pass gradually into sulphides in depth. Cores of black sulphide occur within the green carbonate, and bands of carbonate-ore fork down into the sulphide, becoming narrower in depth, and finally thinning out entirely, give way to sulphide.

Black sulphide, marking the zone of sulphide-enrichment, then constitutes the body of the copper-ore for a considerable distance in depth. This distance varies much, and, owing to deformation of country-rock and lack of development, it cannot be stated definitely. It may be said in a general way, however, that the thickness of the zone of oxides and carbonates is not so great as the thickness of the zone of black sulphides. The transition from the zone of oxidation to the zone of sulphide-enrichment is gradual. It is to be seen in its earliest stage in the slight enrichment along fractures in primary sulphides, in hand specimens, and in thin sections showing various stages in its progress. Thin sections of rich copper-ore made up of black sulphides and chalcopyrite, from the West Emma and Coolidge stopes of Old Jordan mine, reveal details in the progress of this alteration. Massive, porous chalcopyrite in a quartz-gangue is seen to be traversed by many cracks.

Narrow bands of a grayish-black metallic mineral fringe the edges of chalcopyrite, penetrate the mass along these cracks, and even line the walls of interior spaces in the chalcopyrite. Although in some instances intergrowth is rather uncertainly suggested, in many places the black metal is clearly seen to have formed along cracks that were developed after the chalcopyrite had been deposited, and to replace the chalcopyrite.

An advanced stage in this replacement is indicated by a hand specimen from the Commercial mine. Black sulphide-ore makes up the outer portions and yellow sulphide forms the inside portion, between the black sulphide. The boundaries between the two are not sharp, but the black gives way gradually to the yellow, sending finally only narrow stringers into the core. The black material is composed of chalcocite and tenorite, melaconite, probably some tetrahedrite, and tellurium with gold and silver. The yellow core is mainly granular pyrite. In brief, this is believed to show the replacement of a mass of primary sulphide by black copper sulphide.

In addition to affording evidence that the process of enrichment is molecular replacement, this sample also gives valuable information on the occurrence and transfer of values in secondary enrichment. Selected samples of the black sulphide and carefully-picked samples of the yellow sulphide were tested for their values by Dr. Hillebrand and Dr. Allen in the laboratories of the U. S. Geological Survey. The yellow, probably primary sulphide, yielded: gold, 0.1 oz.; silver, 3.32 oz.; a little copper, and a trace of tellurium. The black sulphides yielded: gold, 3.8 oz.; silver, 58.6 oz.; copper, 42.3 per cent., and a proportionately increased amount of tellurium. Dr. Hillebrand is of the opinion that "from the amount of tellurium present it seems probable that the silver and gold both exist as tellurides." This goes to show that not only are the copper values thus highly raised by enrichment, but that gold and silver believed to occur as tellurides are proportionately enriched. The high ratio of values in the primary sulphide to those in the secondary also suggests that, if these added values were derived solely by robbing overlying low-grade primary ores, a large mass would have been required to afford such a large increase.

This enrichment may be observed to proceed gradually until, through the continued relative increase of the secondary sul-

phide and decrease of the primary, the entire mass of an ore-body is made up of high-grade, enriched, black, sulphide-ore. This constitutes the so-called "black sulphide"-ore, which is the richest copper-ore in this camp. In its typical occurrence it is a loose, dry, dull, granular, black, earthy ore, intermingled with gray and grayish-black metallic scales and larger portions. This may frequently be seen inclosing cores of yellow sulphide and intimately associated with chalcopyrite and pyrite. Although this black ore varies in character somewhat, it is found on chemical examination of selected samples from several mines to consist chiefly of chalcocite (black copper sulphide), tenorite (black copper oxide), melaconite (massive earthy variety of the copper oxide, tenorite), some tetrahedrite, and probably some enargite.

Below this zone of sulphide enrichment, low-grade cupriferous pyrite occurs. The passage out of this zone in depth is like the entrance into it, gradual. Within the body of rich black ore, nodules and grains of cupriferous pyrite occur which, in depth, become more numerous and pass into continuous bands which lead to the primary sulphides. The transition from secondary to primary sulphides, begun in this way, progresses by continued decrease of secondary and reciprocal increase of primary sulphides.

The above descriptions present the facts of superficial alteration, including sulphide enrichment, observed in Bingham. It is believed they compose an accordant sequence. In brief, the copper-ore was apparently deposited originally in metamorphosed limestone in the form of the sulphides, pyrite and chalcopyrite. Surface-water containing free oxygen descending through limestone doubtless became carbonated, and in certain instances in percolating through intrusives probably took up some of the component alkalies. The oxidation of the cupriferous sulphides by such carbonated waters would have produced carbonates and oxides of copper. Reduction of these compounds would yield native copper. Beyond this stage, oxidation having ceased and reduction alone characterizing the alteration, secondary sulphides would have formed. Below the downward limit of the formation of secondary sulphides the primary sulphides would remain in their unaltered original state.

7. *Conclusion.*—The general features of the parts which ascending solutions from fissures and intrusives played in the formation of the copper-ore in limestone are clear, although the precise share which each took is not fully determined. In general, it appears that the principal source of the copper-ore in limestone was the magma of the intrusive; that the mineral elements were transported by the intrusives and by thermal solutions and vapors emitted first from their superficial portions and at a later date from their deeper portions, that ore was deposited by molecular replacement of a metamorphosed, at least partly silicified, country-rock, and that they have since been changed in their surface portions by normal superficial alteration into sulphates, carbonates, oxides, and native copper.

VIII. *Periods of Ore-Deposition.*

Two periods of mineralization appear to be indicated by the general occurrence of the ores, but absolute proof is lacking. The occurrence of chalcopyrite and pyrite intergrown with contact-metamorphic minerals adjacent to intrusives on the border of the largest body of copper-ore in the district signifies that some of the copper-ore was formed by contact-metamorphic action at the date of intrusion. The argentiferous lead-ores, however, occur in fissures that traverse the intrusives; accordingly, they were formed after the intrusion. No means of fixing this later date of mineralization has been found; it may have been immediately after the intrusive had cooled to sufficient hardness to allow distinct fissuring. In this case it may be conceived as a later effect or consequence of the intrusion. Or it might have been deposited contemporaneously with the extrusion of andesite, which is believed to have occurred considerably later than the intrusion. The absence of metallic values in the extrusive, so far as known, is unfavorable to the hypothesis that the vein- and lode-ores are contemporaneous with extrusion. It thus appears probable that the vein- and lode-ores were formed subsequent to the date of intrusion—perhaps by after-action. The continuation of bands of lead-ore out from a fissure along beds of limestone, as observed in the Neptune mine, and similarly of cupriferous pyrite, as observed in the Colorado mine, would seem to indicate that some of the ore in limestones, copper as well as

argentiferous lead, was not formed until the second period of mineralization.

In short, the ores of Bingham were probably deposited during two main periods of mineralization, some of the pyritic copper-ore being developed contemporaneously with intrusion, and the argentiferous lead-ores and the remainder of the copper-ore being deposited later—possibly by after-action.

IX. *Dates of Mineralization.*

The date or dates when ore-deposition took place have not been closely fixed. The special difficulty in determining the date of ore-deposition arises from the fact that only a small part of the geologic history—that recorded by a portion of a single formation—can be read within this area, and that this part cannot be precisely correlated with any part of the record of neighboring areas whose geologic history is known, because this region is separated from them by extensive Quaternary deposits. Time limits can be determined, then, only by broad and correspondingly uncertain correlations.

Dates of periods of mineralization are commonly fixed with reference to geologic events of known geologic date. The principal ore-bodies at Bingham which occur in sediments lie entirely within rocks of upper Carboniferous (Pennsylvanian) age. It is known that ore-deposition took place after the deposition of upper Carboniferous sediments, after the epoch of intrusion, and after the formation of NE–SW. fissures. On the other limit it is known that ore-deposition took place before fissuring in NW–SE. directions and secondary movement on NE–SW. fissures. Further, although definite evidence could not be found to prove the age of the NE–SW. and NW–SE. fissures and of ore-deposition as related to that of the epoch of extrusion, it seems probable that ore was deposited long before extrusion occurred. If the period of extrusion in this region was contemporaneous with that of similar extrusions between the Wasatch and Uinta ranges, it took place after Vermilion Creek Tertiary time. On the other limit, the period of intrusion took place later than upper Carboniferous time. According to the closest approximation it is now possible to make by such necessarily broad and uncertain correla-

tions, the ore at Bingham was deposited between upper Carboniferous and Vermilion Creek Tertiary times.

X. *General Conclusions.*

Between Carboniferous and late Tertiary time, monzonitic intrusives invaded sediments in the Bingham area, metamorphosed them, and introduced metallic elements which replaced marbleized limestone with pyritous copper sulphides. After the superficial portions of the intrusives had cooled to at least partial rigidity, they and the inclosing sediments were rent by persistent NE–SW. (and some E–W.) fissures.

Heated aqueous solutions from the deeper unconsolidated portions of the magma then ascended these channels, altered their walls, and introduced additional metallic elements. At this time more pyritous copper sulphide may have been added to that formed earlier in the limestone in connection with contact-metamorphism. Monzonite, including its original metallic constituents, was altered; copper, gold and sulphur were probably added, and auriferous copper sulphides were formed. The silver-lead ore was deposited in the NE–SW. fissures, mainly by filling, partly by replacement.

Since this second period of mineralization these original sulphide-ores have been altered by surface-waters, in their upper portions into carbonates and oxides, and relatively enriched in their underlying portions through replacement by black copper sulphides.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Constitution of Mattes Produced in Copper-Smelting.

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INTRODUCTION.

THE term matte is applied to smelting-products so extremely diverse in composition and physical properties that it appears impossible to devise any generic formula to represent, chemically, the manner in which the varied proportions of the almost unlimited possible constituents combine with each other.

Mattes produced in copper-smelting, in distinction from those produced in smelting-operations in which the recovery of copper is secondary to that of other metals, cover a narrower range in composition. The copper-content of such mattes vary from 20 to 80 per cent., and even this range is much smaller in general practice since it is found advantageous, when possible, to produce mattes with about 50 per cent. of copper in the first operation. Further, it is unusual that arsenic or antimony occurs in copper-ores in sufficient proportions to form arsenides or antimonides in such quantities that they will separate out from the furnace-products, as is common in lead-smelting. Generally, the mattes produced in copper-smelting are composed mainly of copper (usually greater than 35 per cent.), iron and sulphur, the remaining elements being usually in proportions sufficiently small to allow of their treatment as impurities, rather than as essential constituents of the mattes.

In modern practice of smelting copper-ores in blast-furnaces the tendency is to approach pyritic smelting as nearly as possible, the furnaces being low and the air supplied being largely in excess of that required for complete combustion of the carbonaceous fuel. Hence the atmosphere of the blast-furnace thus used is usually oxidizing or nearly neutral, and, as a consequence, the reduction of metallic iron that was a necessary evil of former practice is of unusual occurrence in operations where the main object is the recovery of copper. Hearth-accre-

tions of metallic iron are uncommon, and that metal does not enter into the composition of mattes to the extent that was formerly the case.

Having had occasion to smelt copper-ores composed entirely of copper, iron and sulphur, and free from the impurities usually present, we have examined the resultant mattes with a view to forming a basis for the study of the constitution of the mattes produced in smelting ordinary copper-ores.

Mattes produced in copper-smelting receive technical names more or less indicative of their general appearance. The matte produced in smelting ores usually contains from 35 to 55 per cent. of copper, and is known as "coarse metal." This material is hard, compact, of dull-bronze color and contains no visible metallic copper. When the proportion of copper exceeds 60 per cent. the color of the matte becomes a bluish-purple, and filaments of metallic copper (moss-copper) separate out in considerable quantity. Such matte is known as "blue metal," and retains its characteristics until the proportion of copper approaches 70 per cent. Matte containing from 70 to 76 per cent. of copper has a white, unevenly-plated appearance, and is called "*white metal*," and, though generally of very homogeneous appearance, it frequently contains metallic copper that is visible to the naked eye. When mattes are more highly concentrated, metallic copper separates out in considerable proportion and the accompanying mattes, with from 78 to 81 per cent. of copper, receive various names, "pimple metal," "close regule," "spongy regule," etc., according to their appearance.

Line of Research.

The object of this research being the study, both from a chemical and a physical standpoint, of the constitution of mattes produced in copper-smelting, the investigation involved synthesis and analysis. Synthetic mixtures of copper, iron and sulphur, and their compounds, were subjected to temperatures similar to those of the smelting-operations, and the constitution of the products investigated; and the products of the smelting-operations also were examined.

With a view to determine the chemical combinations in which copper, iron and sulphur occur in mattes, we have examined the action of neutral solutions of silver nitrate upon

the various compounds and mixtures of these elements and their compounds, and this reagent has proved invaluable in the general investigation. The following is a summary of our conclusions:

1. Cuprous sulphide (Cu_2S) is rapidly and completely decomposed according to the following equation.

$$Cu_2S + 4\ AgNO_3 = 2\ Cu(NO_3)_2 + Ag_2S + 2\ Ag.$$

2. Metallic copper readily precipitates metallic silver in equivalent proportions.

$$Cu + 2\ AgNO_3 = Cu(NO_3)_2 + 2\ Ag.$$

3. Cuprous oxide (Cu_2O) precipitates metallic silver and forms a basic nitrate that is insoluble in the reagent.

$$3\ Cu_2O + 6\ AgNO_3 + 3\ H_2O = 6\ Ag + 2\ Cu(No_3)_2 + 2\ Cu_2O, OH, NO_3, H_2O.$$

4. Ferrous sulphide (FeS) is inert.

5. Metallic iron slowly precipitates metallic silver, but great length of time is necessary to complete the reaction.

6. All of the foregoing conclusions apply to the complex mixtures and compounds, produced by fusion, of cuprous sulphide, ferrous sulphide, cuprous oxide, metallic iron and metallic copper.

Copper, Iron and Sulphur Compounds Stable at Fusion-Temperatures.

Copper and Sulphur Compounds.—1. Cuprous sulphide (Cu_2S), fused with sulphur in a closed crucible, after cooling, was crushed and fused again with sulphur. The product, allowed to cool in the crucible, was found to be unaltered in composition.

2. Cuprous sulphide, fused with metallic copper, was left in the furnace for some time at a high temperature. A button of metallic copper was obtained and a regulus that was identical in composition with the original cuprous sulphide.

3. Cupric sulphide (CuS) was fused separately alone, with metallic copper and with sulphur. In every case the product was cuprous sulphide (Cu_2S). Hence it is apparent that the

only compound of copper and sulphur that can exist in a fused state is cuprous sulphide; also that cuprous sulphide will not dissolve an excess of either of its constituents.

Iron and Sulphur Compounds—1. Commercial ferrous sulphide was fused twice with sulphur, the product in each case being allowed to solidify in the crucible. The final product contained 63.52 per cent. of iron, being practically pure ferrous sulphide.

2. Commercial ferrous sulphide was fused with a large excess of iron filings. A button of brittle iron was obtained with a regulus that contained 87.6 per cent. of iron. This was the highest proportion of iron that could be introduced into the product, though all proportions between 87.6 and 63.5 per cent. were possible. The regulus was brittle and contained no visible metallic fragments. This regulus was digested for several days in neutral silver nitrate which dissolved 20 per cent. of the iron, but no attempt was made to obtain complete solution of the iron.

One gram of this regulus was treated with dilute hydrochloric acid in an apparatus arranged to allow of the absorption of the hydrogen sulphide and the subsequent collection of hydrogen. Two experiments, in which only rough corrections were made for temperature and pressure, gave a mean of 248 cc. of hydrogen evolved. Assuming that the whole of the iron in the regulus beyond that required to form ferrous sulphide was metallic iron, and that it would dissolve in acid and form hydrogen, the quantity of gas evolved at normal temperature and pressure would have been 252 cc., a figure sufficiently close to the experimental results to show that the regulus consisted of a solid solution of metallic iron in ferrous sulphide.

These results show that compounds of iron and sulphur with higher proportions of sulphur than that contained in ferrous sulphide cannot be formed by fusion, but that the proportion of sulphur may be considerably reduced, the minimum being probably reached at about 13 per cent. The lower proportions of sulphur are, however, the result of solution of metallic iron in ferrous sulphide, rather than to the formation of chemical compounds with greater proportions of iron than in ferrous sulphide.

Finally, ferrous sulphide appears to be the only compound of the two elements possible in materials that have been subjected to fusion.

Cuprous Sulphide and Metallic Iron.—Cuprous sulphide was fused in a crucible and rods of iron introduced into the molten material of sufficient thickness to insure that they would not melt during the time the crucible was in the furnace. A button of metallic copper was obtained and a regulus containing:—copper, 60.6; iron, 17.8; and sulphur, 21.6 per cent.

This regulus was decomposed by neutral silver nitrate and was found to contain cuprous sulphide, 56.3; ferrous sulphide, 28.0; and metallic copper, 15.7 per cent.

Metallic iron decomposes cuprous sulphide according to the equation;—

$$Cu_2S + Fe = FeS + Cu,$$

and the ferrous sulphide, so formed, mixes with the cuprous sulphide and yields finally a regulus, containing about 30 per cent. of ferrous sulphide, that is not decomposed by metallic iron.

Ferrous Sulphide and Metallic Copper.—Ferrous sulphide, prepared by precipitation, was fused with a large excess of metallic copper, yielding a button of copper and a regulus composed of iron, 25.0; sulphur, 14.3; and copper, 60.7 per cent.

Ferrous sulphide dissolves metallic copper in all proportions up to 120 per cent. of its weight.

This action was one of solution and not of decomposition, as was shown on attacking the regulus with a solution of silver nitrate. The quantity of precipitated silver amounted to 208 per cent. of the regulus treated and was equivalent to the metallic copper.

Double Sulphides of Copper and Iron.—Solutions of cupric and ferrous sulphates were mixed in varying proportions and the metals precipitated thererfom as sulphides. After washing the precipitates they were fused under a layer of glass in closed crucibles. The products were apparently homogeneous and had the compositions given in Table I.

Cuprous and ferrous sulphides in all proportions may be fused together to form apparently homogeneous products, and

TABLE I.—*Composition and Calculated Constitution of Double Sulphides of Iron and Copper.*

Components.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Copper...............	78.5	72.1	63.5	56.2	34.2	23.4
Iron....................	1.1	6.1	13.0	18.8	36.4	45.6
Sulphur	20.4	21.8	23.5	25.0	29.4	31.0
	100.0	100.0	100.0	100.0	100.0	100.0
Calculated Constitution.						
Cuprous sulphide..	98.3	90.4	79.6	70.4	42.8	29.3
Ferrous sulphide..	1.7	9.6	20.4	29.6	57.2	70.7

the double sulphides referred to in Table I. were fused with an excess of metallic copper, yielding the results set forth in Table II.

TABLE II.—*Composition and Calculated Constitution of Double Sulphides of Iron and Copper.*

Components.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Copper...............	80.4	72.1	63.9	60.7	57.5	57.3
Iron....................	1.0	6.1	12.9	16.8	23.5	25.1
Sulphur..............	18.6	21.8	23.2	22.5	19.0	17.6
Physical characteristics.	Hard, compact. Gray-colored, showing some metallic copper.	White, compact, very homogeneous—typical white metal.	Bluish-white, with many cavities, showing some metallic copper.	Bluish, compact.	Bronze-colored.	Bronze-colored, excess of copper not well separated.
Calculated Constitution.						
Cuprous sulphide..	89.2	90.4	78.5	63.7	27.7	16.5
Ferrous sulphide..	1.5	9.6	20.2	26.4	36.9	39.4
Metallic copper...	9.3	....	1.3	9.9	35.4	44.1

Double sulphides of copper and iron, with the exception of No. 2 in Table II., have the property of dissolving metallic copper. The regulus, consisting approximately of 90 per cent. of cuprous sulphide and 10 per cent. of ferrous sulphide, having all the characteristics of white metal, appears to form a divid-

ing line between the double sulphides, in which the excess of copper is held in mechanical suspension, and those in which ferrous sulphide acts as a solvent.

Magnetic Iron Oxide in Mattes.—By dissolving the mattes produced in copper-smelting in nitric acid an insoluble black powder frequently remains. This powder consists of magnetic iron oxide (ferroso-ferric oxide). A sample of matte made in a reverberatory furnace from which a considerable proportion of this residue separated on solution consisted of copper, 54.9; iron, 22.4; and sulphur, 22.7 per cent. There were no impurities present apart from minute proportions of gold and silver.

This matte was finely ground and digested in various solvents, first in the cold and finally at a boiling temperature. The residues were collected as in gold-parting, and the following data were obtained:

Solvent.	Residue. Ferroso-Ferric Oxide.
	Per Cent.
20 cc. nitric acid, 1 g. potassium chlorate..........	2.30
20 cc. nitric acid, 2 g. potassium chlorate..........	2.60
20 cc. nitric acid, 5 g. potassium chlorate..........	3.63
20 cc. nitric acid..	1.86
20 cc. dilute nitric acid..................................	1.90
15 cc. nitric acid, 10 cc. sulphuric acid............	nil.

The foregoing determinations show the proportion of the ferroso-ferric residue to be very variable, and, moreover, that the proportion increases with the oxidizing energy of the solvent used. Magnetic iron oxide which is formed at high temperatures is quite insoluble in concentrated sulphuric acid, whereas the residues from the experiments were readily soluble in that reagent. It appears therefore that the ferroso-ferric oxide is the result of precipitation by the oxidizing agent, rather than an original constituent of the matte. While the foregoing experiment only indirectly proves the non-existence of ferroso-ferric oxide as a constituent of mattes, subsequent data is given that explain the constitution of mattes without making allowance for this, to say the least, doubtful constituent.

Mattes from Copper-Smelting.

Samples of matte of increasing proportions of copper were obtained, which were composed entirely of copper, iron and

TABLE III.—*Results Obtained by Treating Copper-Mattes with Silver Nitrate.*

Sample.	Copper.	Iron.	Sulphur.	Residue.	Copper in Residue.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
No. 1...	49.7	27.0	23.3	220	nil.
No. 2...	55.6	21.6	22.8	233	nil.
No. 3...	61.2	16.4	22.4	247	nil.
No. 4...	66.8	11.4	21.8	260	nil.
No. 5...	70.8	7.6	21.6	271	nil.
No. 6...	71.7	6.4	21.9	274	nil.
No. 7...	72.1	6.2	21.6	273	0.6
No. 8...	74.8	4.2	21.0	280	0.6
No. 9...	78.0	1.8	20.2	287	0.6
No. 10...	79.2	1.0	19.8	290	0.8
No. 11...	80.1	0.4	19.1	292	1.6

Residues.

Sample.	Weight.	From Ferrous Sulphide.	From Cuprous Sulphide.	From Metallic Copper.	From Cuprous Oxide.
		Ferrous Sulphide.	$Ag_2S + 2\ Ag$.	2 Ag.	$6\ Ag + 2\ Cu_2O, OH, NO_3, H_2O$.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
No. 1...	220.7	42.4	114.4	63.9	nil.
No. 2...	234.9	33.9	152.3	48.7	nil.
No. 3...	248.5	25.8	188.4	34.3	nil.
No. 4...	261.8	17.9	223.0	20.9	nil.
No. 5...	271.8	11.9	251.0	8.9	nil.
No. 6...	274.5	10.0	264.5	nil.	nil.
No. 7...	274.1	9.7	263.0	nil.	1.4
No. 8...	280.5	6.6	270.0	2.5	1.4
No. 9...	288.3	2.8	278.0	6.1	1.4
No. 10...	291.1	1.5	278.0	9.5	2.1
No. 11...	293.0	0.6	276.0	11.7	4.7

Calculated Constitution.

Sample.	Cuprous Sulphide.	Ferrous Sulphide.	Metallic Copper.	Cuprous Oxide.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
No. 1......	39.0	42.4	18.6	nil.
No. 2......	51.9	33.9	14.2	nil.
No. 3......	64.2	25.8	10.0	nil.
No. 4......	76.0	17.9	6.1	nil.
No. 5......	85.5	11.9	2.6	nil.
No. 6......	90.0	10.0	nil.	nil.
No. 7......	89.5	9.7	nil.	0.6
No. 8......	92.0	6.6	0.8	0.6
No. 9......	94.8	2.8	1.8	0.6
No. 10......	94.8	1.5	2.8	0.9
No. 11......	94.0	0.6	3.4	2.0

sulphur, except for minute proportions of gold and silver. These finely-divided samples were digested in solutions of neu-

tral silver nitrate and the resulting residues contained,—the whole of the ferrous sulphide; metallic silver and silver sulphide equivalent to the cuprous sulphide; metallic silver equivalent to metallic copper if present; and basic copper nitrate and metallic copper equivalent to any cuprous oxide.

The solutions were examined for iron and in no instance was it found; hence none of the samples contained metallic iron, for the reason that this metal, even when dissolved in ferrous sulphide, decomposes silver nitrate though the action is slow.

The analytical data obtained from these samples of copper-matte are given in Table III.

In order to determine whether the excess of copper was held mechanically, or whether actual solution had taken place, the samples were fused in closed crucibles and the molten mass allowed to solidify in the furnace. Buttons of metallic copper were obtained only from samples Nos. 8, 9, 10 and 11, partly from fusion together of globules and partly from the reduction of copper by the reaction of copper sulphide and copper oxide, as is shown in Table IV.

TABLE IV.—*Results Obtained.*

Sample.	Metallic Copper Obtained.	From Cuprous Oxide.	In Original Matte.
	Per Cent.	Per Cent.	Per Cent.
No. 8	1.70	0.80	0.90
No. 9	2.50	0.80	1.70
No. 10	4.00	1.20	2.80
No. 11	5.10	2.60	3.50

The data in Table IV. agree with the calculated quantities, and show that the whole of the excess of metallic copper is held in mechanical mixture. Metallic copper was produced by fusing sample No. 7, but the buttons formed were too small to be collected. The excess of metallic copper is evidently held in solution by ferrous sulphide when that compound forms more than 10 per cent. of the matte; whereas, when less than 10 per cent. is present, the metallic copper, if present, is held in mechanical suspension.

We have given the name of white metal to the matte that contains 90 per cent. of cuprous sulphide and 10 per cent. of ferrous sulphide, and we distinguish it from other mattes ap-

proximating this composition that are, from their physical appearances, generally classed under that name. We have used the name white metal, for lack of a better one, to indicate the matte in which the combination of the metals with sulphur exactly satisfies the chemical requirement and, when copper, iron and sulphur, constituting the whole matte, it corresponds to the formula 5 Cu_2S, FeS.

Physical Properties.—The samples Nos. 1 to 6, in Table III., were quite homogeneous in appearance, whereas the others contained metallic copper visible to the naked eye. Samples Nos. 3 and 4 were taken from bulks in which a considerable proportion of moss-copper occurred, but it was possible to select matte that was quite free from this material. This was not the case with samples Nos. 7 to 11, in which finely divided metallic copper was intimately mixed.

Microscopic Examination.—Portions of all of the samples were polished and examined under the microscope. The samples were almost identical in appearance, except that samples Nos. 7 to 11 showed metallic copper. The matte portion of the samples were grayish-black in color and of very uniform appearance.

The samples were polished and subsequently attacked by dilute solutions of silver nitrate which gave the following data:—

Sample No. 6 (white metal) was uniformly coated with a dull-gray material which was probably a mixture of metallic silver with sulphides of silver and iron.

Samples Nos. 1 to 5 had a ground-work identical in general appearance with sample No. 6. In this specimen were irregular patches of a dark-gray material containing glistening crystals of metallic silver.

Samples Nos. 7 to 11 were mainly similar to sample No. 6, but contained innumerable glistening facets of metallic silver uniformly distributed over the gray coating.

These observations, we think, show that white metal ($5Cu_2S$, FeS) enters into the composition of samples Nos. 1 to 5. The sample that satisfied this formula is perfectly homogeneous. When ferrous sulphide occurs in mattes in excess of the proportion required for this formula, the excess separates from the white metal on cooling. The excess of ferrous sulphide is the agent that dissolves the metallic copper occurring in these

mattes as is demonstrated by the precipitation of metallic silver in crystals of considerable size upon the dark patches of ferrous sulphide.

The constitution of mattes in which the cuprous sulphide is in excess of that required by the formula for white metal is not so obvious from the foregoing results. That metallic copper occurs disseminated through the mass is shown by the formation of innumerable independent crystals of metallic silver. The products obtained by attacking white metal and cuprous sulphide with silver nitrate are, however, so nearly alike that the attacked surfaces of these mattes present a uniform appearance except for the crystals of metallic silver formed by the metallic copper.

Owing to the unsatisfactory re-solution by silver nitrate of the constituents in samples Nos. 7 to 11, the sections were repolished and etched with potassium cyanide. Upon re-examination it was found that sample No. 6 (white metal) was very uniformly etched, consisting mainly of a light-gray material in the midst of which were innumerable uniformly distributed dark-colored minute particles. Samples Nos. 1 to 5 consisted of a ground-work similar to white metal, in which were light-gray patches markedly isolated from the main body. The proportion of these patches to the whole increased with the proportion of iron in the sample.

In samples Nos. 7 to 11, the uniform structure of sample No. 6 gradually gave place to a mixture of material similar to that of sample No. 6, with steel-gray patches until, in sample No. 11, the mass was composed almost entirely of this gray material, occasionally having enclosed patches of material similar to sample No. 6. Metallic copper was visible.

These observations fully confirm those made on the samples attacked by silver nitrate. Ferrous sulphide is not acted upon by potassium cyanide, whereas both metallic copper and cuprous sulphide are attacked. Sample No. 6 is obviously composed of a chemical construction of cuprous sulphide and ferrous sulphide. As was observed, no such uniform and intimate mixture of these two sulphides could be obtained except from the decomposition of a chemical compound. In samples Nos. 1 to 5 the light-gray patches were obviously due to the action of the re-agent on the metallic copper dissolved in ferrous sulphide.

The extraction of this metal from the solid solution left the ferrous sulphide fresh and bright in a way that would be impossible to obtain by mechanical polishing. The ground-work was obviously white metal. In samples Nos. 7 to 11 the gradual decomposition of the white metal was distinctly noticeable, and its replacement by cuprous sulphide was evident by the gradually increasing proportion of steel-gray material which could only be evenly-etched cuprous sulphide.

Pyrometric Measurements.—The following determinations of melting-points were made:

Sample.	Copper-Content.	Melting-Point.
	Per Cent.	Degrees C.
A................	32.6	875
1................	49.7	955
3................	61.2	1,070
6................	71.7	1,121
11................	80.1	1,098
Metallic copper.	100.0	1,083

These temperatures are those at which the main solidification of the melted samples took place. We did not have sensitive recording-apparatus that might have shown the mattes to be made up of two or more components of different melting-points. In the case of sample No. 11 it might have been expected that the copper mechanically held by the matte would have caused a definite arrest in the cooling-curve at 1,083° C., but when this matte is melted, the excess of metallic copper collects at the bottom of the containing-crucible and is out of contact with the pyrometer.

White metal has the highest melting-point of the whole series, and any addition of either component beyond the proportions required to satisfy the formula, 5 Cu_2S, FeS, causes a fall in the melting-point. This fact is additional evidence of the probability that the matte we have called white metal is a chemical compound.

Matte Concentration.—The probable existence of the compound, 5 Cu_2S, FeS, in mattes, puts us in a position to explain the phenomena attending the concentration of mattes in copper-smelting. The analytical data given in Table III. may also be arranged as in Table V.

TABLE V.—*Rearrangement of Data Given in Table III.*

Sample.	Ferrous Sulphide.	White Metal.	Cuprous Sulphide.	Metallic Copper.	Cuprous Oxide.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
No. 1.....	38.1	43.3	nil.	18.6	nil.
No. 2.....	28.1	57.6	nil.	14.2	nil.
No. 3.....	16.7	71.4	nil.	10.0	nil.
No. 4.....	9.5	84.5	nil.	6.1	nil.
No. 5.....	2.4	95.0	nil.	2.6	nil.
No. 6.....	nil.	100.0	nil.	nil.	nil.
No. 7.....	nil.	97.0	2.2	nil.	0.6
No. 8.....	nil.	66.0	32.6	0.8	0.6
No. 9.....	nil.	28.0	69.6	1.8	0.6
No. 10.....	nil.	15.0	81.3	2.8	0.9
No. 11.....	nil.	6.0	88.6	3.4	2.0

The principal chemical reactions that take place in copper-smelting result in the formation of metallic copper, although the presence of sulphides may produce cuprous sulphide from the copper so formed. It has generally been considered that metallic copper formed prior to the stage at which it collects as a copper-bottom, is only a theoretical conception, the enrichment of mattes being attributed to processes of oxidation. We consider that the foregoing experimental work shows that metallic copper is actually formed at all stages of copper-smelting, and that it exists in the various products either held in solution by ferrous sulphide or mechanically mixed with the matte.

Samples Nos. 1 to 5 in Table V. show that the ratio of the ferrous sulphide (after eliminating that required to form the compound 5 Cu_2S, FeS) to the metallic copper gradually decreases. In other words, the excess of ferrous sulphide holds a greater proportion of metallic copper. Apparently, under the conditions of copper-smelting, ferrous sulphide becomes supersaturated with metallic copper when it has dissolved 60 per cent. of its weight, and, on cooling, it gives up a portion of the dissolved copper as moss-copper. This is probably the reason why the formation of moss-copper is only observed in mattes containing from 60 to 70 per cent. of copper. It has been shown conclusively that the matte we have called white metal does not dissolve metallic copper, consequently any copper that may be formed at this stage is apparently re-sulphidized. This matte, however, is only a boundary-line, and, when the concentration passes it, we have further evidence that ferrous sulphide in excess of that required to satisfy the

formula 5 Cu_2S, FeS is capable of dissolving metallic copper. When the concentration is carried beyond white metal, the mattes still contain metallic copper; but it is held in mechanical suspension only. The principal action at this stage appears to be the decomposition of the compound 5 Cu_2S, FeS. Metallic copper and cuprous oxide are formed, and are held mechanically by the matte; but it is not until the white metal is practically all decomposed that metallic copper is formed in sufficient quantity to separate from the matte in the form of copper-bottoms.

Impurities in Mattes.—The foregoing conclusions refer to mattes composed entirely of copper, iron and sulphur. This condition is most unusual, copper-ores being generally associated with minerals the constituents of which are reduced with the copper in the ordinary smelting-processes. The elements that may enter into the composition of mattes produced in copper-smelting are innumerable, but so far as this investigation is concerned, they never occur in the proportions common to other smelting-operations.

The proportions of the impurities occurring in mattes produced in copper-smelting are almost invariably sufficiently small to render immaterial the exact state of chemical combination in which they occur.

Table VI. gives analyses of mattes containing typical proportions of the more common impurities.

TABLE VI.—*Composition of Typical Mattes Containing Impurities.*

Components.	1.	2.
	Per Cent.	Per Cent.
Copper	72.91	54.06
Iron	5.00	22.15
Sulphur	21.15	22.50
Arsenic	0.47	0.23
Antimony	0.11	0.04
Bismuth	0.06	0.06
Nickel	0.25	0.87
Total	99.95	99.91

From the readiness with which arsenides and antimonides are formed when highly arsenical and antimonial ores are smelted, as well as the volatility and unstability of the sulphides of these elements, we may assume that these elements

replace sulphur in mattes, combining mainly with iron and nickel. The other common elements probably occur as sulphides.

The exact form of chemical combination in which the various elements occur in mattes could only be determined by a laborious series of experiments, but the proportions under consideration are small and do not affect the following generalization that aims at an explanation of the effects of impurities upon the operations of copper-smelting.

The analyses given in Table VI. may be rearranged so as to show the constitution of the materials. This is done in Table VII.

TABLE VII.—*Rearrangement of Data in Table VI. in Order to Show the Constitution of the Materials.*

Components.	1.	2.
	Per Cent.	Per Cent.
Cuprous sulphide	91.16	45.20
Metallic copper	0.20	18.25
Iron and nickel sulphides	7.58	35.99
Bismuth sulphide	0.07	0.07
Iron and nickel arsenide	0.82	0.35
Iron and nickel antimonide	0.16	0.06
Total	99.99	99.92
Assuming the presence of white metal, $5\,Cu_2S,\ FeS$.		
	1.	2.
	Per Cent.	Per Cent.
White metal	83.3	50.2
Cuprous sulphide	14.3	nil.
Ferrous sulphide	nil.	31.0
Metallic copper	0.2	18.2
Total	97.8	99.4

A comparison of the results obtained from impure mattes (Tables VI. and VII.) with those obtained from similar mattes having the same proportions of copper, but free from impurities (Tables I. and II.), shows that impurities in mattes have a tendency to reduce the proportion of white metal, a fact which has a marked effect upon the treatment of pure mattes. A 75 per cent. copper-matte, obtained from smelting more or less impure materials, will commonly contain less than 2 per cent. of

iron; but pure copper-mattes, containing 78 per cent. of copper, will usually have fully 2 per cent. of iron, and it is only after a considerable proportion of metallic copper has been separated out that a matte comparatively free from iron is obtained. We have always experienced greater difficulty in concentrating pure mattes beyond 70 per cent. of copper than mattes having the ordinary proportions of impurities.

The data given above show that a matte having 72 per cent. of copper, and the ordinary proportions of impurities, contains 14 per cent. of cuprous sulphide, which is ready for reduction to metallic copper, and 83 per cent. of white metal, whereas a pure matte of similar grade contains only 2 per cent. of cuprous sulphide and 97 per cent. of white metal. It is probable that practically the whole of the white metal must be decomposed before metallic copper can form in any considerable proportion, and, as impurities apparently have the effect of decreasing the proportion of white metal in any grade of matte, the effect of these impurities will be to facilitate the separation of metallic copper. This effect is entirely upheld in practice.

Conclusions.

We have deduced the following conclusions concerning the constitution of mattes produced in copper-smelting.

1. Cuprous and ferrous sulphides combine to form a chemical compound corresponding to the formula 5 Cu_2S, FeS. We have called this compound white metal.

2. White metal enters into the composition of all mattes.

3. Fused white metal is capable of mixing with all proportions of fused ferrous sulphide, and these constituents separate independently of each other during the solidification of the mixture.

4. All mattes containing an excess of ferrous sulphide are, by virtue of the presence of this compound, capable of dissolving metallic copper which may or may not separate out according to the degree of saturation of the ferrous sulphide.

5. Fused white metal and fused cuprous sulphide mix together in all proportions, but it is ouly from mixtures in which white metal is in small proportion that metallic copper is readily separated by processes of oxidation.

6. Fused mixtures of white metal and cuprous sulphide can hold metallic copper and cuprous oxide in mechanical suspension.

7. Impurities in mattes, by displacing a portion of the ferrous sulphide available for the formation of white metal, reduce the proportion of the latter compound.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Origin of Vein-Filled Openings in Southeastern Alaska.*

BY ARTHUR C. SPENCER, WASHINGTON, D. C.

(Washington Meeting, May, 1905.)

IN extension of a suggestion already made to account for certain features observed in the Juneau gold-belt in southeastern Alaska,[1] it is the object of the present paper to indicate in detail certain conditions in which deformation of rocks under their own weight might lead to the production of fractures in which veins could be deposited.

A direct, uniformly-distributed pressure of sufficient intensity applied to an elastic brittle mass offering strong resistance to deformation produces rupture. In a material of ideal properties the surfaces of rupture under such pressure would be shearing planes inclined at 45° to the line of force, unless there be preliminary deformation, in which case this angle would be greater than 45°. This general conclusion, resting upon analytical mechanics, is completely supported by the results obtained by Daubrée in experiments upon the deformation of wax and resin prisms under compression. Let us then first consider one of Daubrée's diagrams. In the case illustrated in Fig. 1, four sets of fractures in two approximately right-angled pairs (that is to say, in conjugate sets) were produced by endwise compression of the square cross-sectioned prisms. These fractures cut the axis of compression at approximately equal angles, not varying greatly from 45°. The location of the four sets of fractures is obviously determined by the shape of the prism, since the material in each corner acts in a way as a buttress, permitting the bulging to take place most readily on the sides. By limiting the directions in which bulging may take place, results of a more simple nature could be obtained. Take, for instance, a square prism and place it between two fixed and

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[1] Geology of the Treadwell Ore-Deposits, *Trans.*, xxxv., 508.

rigid walls. Under end-wise pressure, deformation can take place only by bulging out upon the two free surfaces. It is apparent, then, that under these conditions rupture will occur along only two sets of fractures, as shown in Fig. 2, and, as in the first case, the fractures will be symmetrically disposed in reference to the axis of pressure.

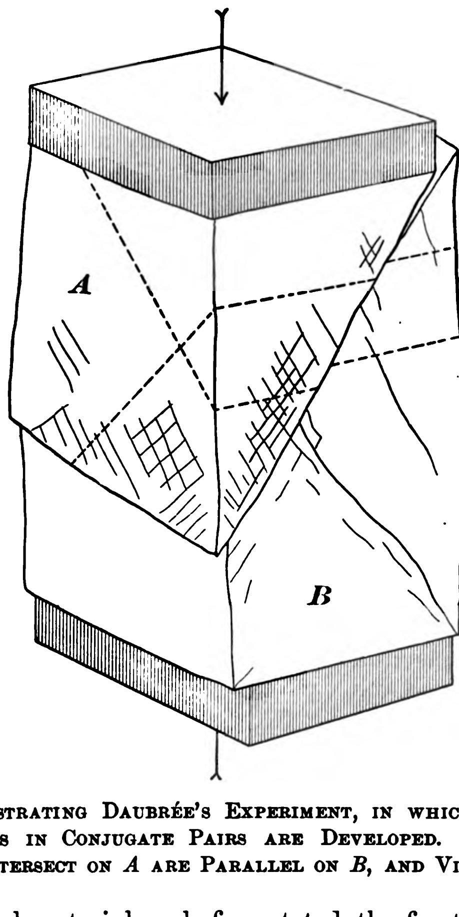

FIG. 1.—ILLUSTRATING DAUBRÉE'S EXPERIMENT, IN WHICH FOUR SETS OF FRACTURES IN CONJUGATE PAIRS ARE DEVELOPED. THE FRACTURES WHICH INTERSECT ON *A* ARE PARALLEL ON *B*, AND VICE VERSA.

In an ideal material, as before stated, the fractures produced by compression will intersect the axis of pressure at an angle of 45°. Suppose that in such an ideal material two sets of fractures showing conjugate relations are found, but that differential motion has not taken place or cannot be determined by inspection of the fractured surfaces. It is evident that observation will not lead to establishing the direction in which the rupturing force was applied because there are two possible

axes from which to choose. Thus, in Fig. 3, the compression causing rupture on *aa* and *a'a'* may have been applied along *HH* or along *VV*.

Considering fractures in nature, the foregoing deductions may be applied in a general way without taking up the modification in the angles between fractures, due to non-homogeneity and lack of perfect elasticity in the rocks, or to preliminary deformation by cubic compression.

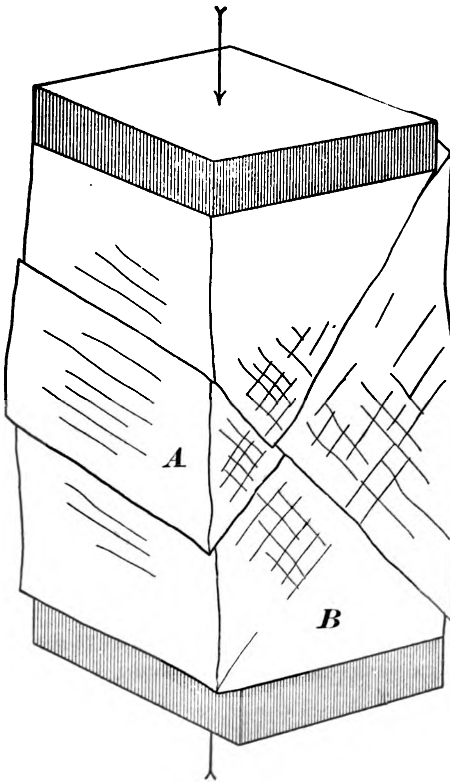

FIG. 2.—FRACTURE IN A SQUARE PRISM FREE RESTRAINED ON TWO OPPOSITE SIDES, *B*, BUT FREE TO DEFORM ON THE REMAINING SIDE, *A*. RESULT: TWO SETS OF FRACTURES IN CONJUGATE RELATION.

For a case of comparative simplicity, it may be imagined that a block of the lithosphere is moved out of its place in a direction opposed to gravity, or, what amounts to the same thing, the surrounding rocks may be supposed to have been drawn away from any block. By such an adjustment of masses equilibrium in the blocks is disturbed, and, because the

restraint of the neighboring masses has been removed, there will be a tendency for the block which is differentially raised to flatten out under the action of gravity. In deformation under these conditions the weight of the block takes the place of an outside force which is commonly called upon in accounting for fractures observed in the rocks. If the sides of the raised block are unrestrained to a sufficient depth, depending upon the strength of the materials involved, the flattening must take place in order to restore equilibrium within the mass. This case is analogous to the deformation or rupture of a column of granite or marble in the ordinary crushing test of the laboratory. In both cases, as in the experiments of Daubrée, strain beyond the ultimate strength of the material will result

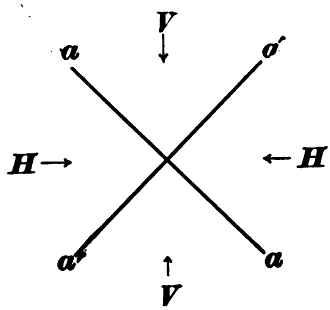

FIG. 3 —ILLUSTRATING THE TWO POSSIBLE AXES OF PRESSURE IN THE CASE OF CONJUGATE FRACTURES—*H H*, *V V*, FORCES; *a a*, *a′ a′*, FRACTURES.

in fractures due to shear, and these fractures will occur in sets equally inclined to the axis of pressure. If the block were a cylinder free to deform in any direction, fractures would be equally liable to open in all azimuths, and out of an indefinitely large number of possible rupture-surfaces those actually developed would be determined by fortuitous conditions.

On the other hand, it may be granted that in a block of any shape, restraint on certain sides would tend to reduce the number of fractures, and in the simple case of a long block with nearly parallel sides which had been moved differentially to a position above the neighboring blocks, or from which the pressure has been relieved on two sides, the tendency would be the production of two sets of fractures striking parallel with the

axis of the block and with opposite dips equally inclined to the direction of gravity.

In the case above stated, the direct or effective cause of the fractures would be gravity, though the ultimate cause would reside in the forces bringing about the postulated movement of the several earth-blocks. Likewise in any real case, though the two forces would necessarily act together and not separately, gravity would still be the efficient factor, since compressive shear would not result from a simple uplifting movement without the resistance due to the weight of a mass of rock sufficient to produce rupture alone.

It is probable that fissures produced in this way would so closely resemble others developed under horizontal thrust normal to the long axis of the block, that only the most careful observation would furnish data for discrimination between them. In the case of vertical pressure, the phenomena of displacement and differential movement would be those compatible with vertical shortening and extension across any horizontal surface, while lateral pressure would induce vertical extension and horizontal shortening. That is to say, in the first case normal faulting would be expected, and in the second case abnormal or thrust faulting.

The particular case which has been deduced corresponds with the tectonic features which exist in southeastern Alaska, where a broad mountainous zone, lying between the plateau region of the interior and the submerged plateau which borders the Pacific, rises about 5,000 ft. above the former and no less than 15,000 ft. above the latter. Standing so far above the neighboring earth-blocks, it seems that in this great orographic mass there must even now exist a tendency to bulge toward the unrestrained sides. If so, conditions are favorable for the opening of fractures at a depth dependent upon the crushing strength of the rocks which compose the great mountainous mass.

The region is one of metalliferous veins, and it is found that a very large number of vein-openings fall into two sets having a common strike nearly parallel with the NW–SE. axis of the orographic block, and opposite dips at about equal angles with the vertical. While the actual dips vary from place to place and the angle between the two sets is not

always the same in places where both of them are observed, they approach as closely to conjugate relations as could be expected in nature.

It must be supposed, as Dr. Becker has suggested in his description of the Treadwell ore-deposit,[2] that these fractures were caused by compressive strain. The additional suggestion made by him that the effecting pressure was applied laterally in a NE–SW. direction seems less acceptable with the foregoing discussion of possibilities in mind. I failed, however, while in the field to establish any observational basis for deciding the actual direction of the forces, though I am by no means satisfied that the point cannot be settled by more critical studies than those which have been made. Dr. Becker's statement that in the vicinity of Juneau the faulting on the fractures occupied by the veins is normal, is to be noted as favoring the vertical direction of the force causing fracture, provided that both rupture and faulting are attributed to the same date and the same general movement in the earth's crust.

If the observed vein-openings were formed in the manner here suggested, their production would have been the result of an ancient differential movement quite similar to that by which the present Coast Range is believed to have been raised above the interior plateau and the floor of the Pacific ocean.[3] In other words, the same processes which have resulted in the existing tectonic feature of southeastern Alaska would have been sufficient, at an earlier period, to produce the phenomena which it is desired to explain. On the uniformitarian principle, therefore, the hypothesis which has been developed is *a priori* an acceptable one.

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[2] 18*th Annual Report*, U. S. Geological Survey, Pt. III., p. 67.

[3] The Pacific Mountain System in British Columbia and Alaska, *Bulletin of the Geological Society of America*, vol. xiv., pp. 117–132 (1903).

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Limestone-Granite Contact-Deposits of Washington Camp, Arizona.

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(British Columbia Meeting, July, 1905.)

Introduction.

WASHINGTON CAMP, in Santa Cruz county, Arizona, is a small and little known mining district situated on the lower, eastern slope of the Patagonia mountains, about 20 miles east of Nogales and a like distance south of Patagonia Station on the Sonora railroad, which connects at Benson, 83 miles from Nogales, with the main line of the Southern Pacific. This district is also about 4 miles north of the international boundary, 35 miles west of Bisbee and 40 miles north of Cananea, in Sonora. The topography of the district, which lies at a general elevation of 5,500 ft. above the sea, is only very moderately rugged, and presents no obstacles to mining operations.

Although some of the claims of the camp, including the Pride of the West, Belmont and Holland, were extensively worked for silver, 25 years ago, they passed, at moderate depths, as in so many other districts, out of the argentiferous lead carbonate and sulphide into zinc, copper and iron sulphides; and for two decades the camp was abandoned and almost forgotten. In recent years, however, its apparent possibilities as a copper producer have led to a revival of mining activity; but not, as yet, with conspicuous success.

Although economically relatively unimportant, the deposits of Washington Camp are, mineralogically and structurally, nevertheless, typical examples of ore-bodies developed in connection with the garnet ledge now recognized as a normal feature of granite-limestone contacts; and, in the opinion of the writer, this is an instance where a minor example is yet essentially normal and capable of throwing important light upon the origin and genetic relations of the type.

I visited Washington Camp in 1901, and again in 1902; and have devoted, in all, about a week to the study, in the field, of the geologic relations of its ore-deposits, adding, incidentally, a suite of the rocks and ores to the economic geologic collections of the Massachusetts Institute of Technology.

General Geology.

Washington Camp consists (geologically) of an irregular area of limestone and quartzite of uncertain age, about 7,000 ft. in extreme length north and south, and 3,000 ft. in maximum breadth east and west. This body of sediments is bordered on all sides by igneous rocks—granite and porphyry; and it may be regarded as an island in the sea of granitic rocks composing the main part, at least, of the Patagonia range. The granite and the porphyry (which is clearly a somewhat later phase of the granite) are newer than the sedimentary rocks and have been erupted through the latter; and the area in question is simply a remnant of the original formation which was so deeply engulfed by the igneous rocks that it has survived the extensive erosion which has long since swept away the rest of the sedimentary cover of the granite over an area of many hundreds of square miles. That the erosion has been extensive we have also positive proof in the coarsely crystalline character of most of the granite and in the highly metamorphic character of the limestone, even at points remote from the border of the granite. The sedimentary rocks are not now absolutely continuous, but several detached masses occur in the granite along the eastern border of the main area; and the latter is more or less completely divided towards its western margin by several large north-south dikes of granite. Although no fossils have survived the metamorphism of the limestone by which its geological age might be determined, there is no reason to doubt that it is a part of the great Paleozoic limestone formation so characteristic of many of the mining districts throughout the entire Rocky mountain region.

The strata are highly inclined at all points, but the dip varies greatly in direction and amount; the prevailing dip, however, is to the west at angles of from 30 to 90 degrees, but mostly above 60 degrees; while toward the eastern border the dip, at a few points, is reversed, or easterly, at similarly high angles;

and, in general, it may be said that the stratification is highly disturbed, with, in some cases, abrupt and extreme variations in strike and dip.

Beginning on the west side of the belt we have:—first, a band of quartzite from 100 to several hundred feet wide, which may, tentatively, be regarded as of Cambrian age. Following this, and magnificently developed in Washington mountain, the highest point in the district, is a massive limestone, characterized by numerous narrow bands and lenses of chert. Dividing the limestone on the eastern slope of Washington mountain is a second band of quartzite, at least 100 ft. thick. This is followed by a broad band of blue, crystalline limestone, or marble, extending well down toward the base of the mountain. Still, farther east, this limestone is interstratified with one or more heavy beds of chert, which, having commonly a somewhat crystalline character, are usually called quartzite. On the eastern slope of the mountain are also to be seen the great dikes of granite, three in number, previously referred to, the most easterly of these dikes forming the hanging-wall of the Pride of the West mine. This brings us approximately to the middle of an east-west section of the sedimentary series; but farther east the limestone is comparatively free from chert bands, presenting extensive bodies of gray to white, crystalline marble in which the stratification is often very indistinct.

It thus appears quite certain that the section is not repeated or folded upon itself; and, notwithstanding the prevailing westerly dip, it is probable that the western quartzite is the oldest member of the series; and the entire formation may, therefore, be regarded as partially inverted.

The sedimentary series is, apparently, conformable throughout; and one is tempted to correlate the western or assumed basal quartzite of the Washington mountain section with the Bolsa quartzite of the Bisbee district, described by Ransome.[1] The latter, however, with a maximum thickness of 430 ft., is seen to rest unconformably upon the Pinal or Algonkian schists; while the former, though not so thick, is everywhere in igneous contact with the granite, and it is improbable that its full normal thickness is now exposed. The limestone fol-

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[1] *Folio* 112, United States Geological Survey.

lowing this quartzite and forming the main mass of Washington mountain becomes, then, the equivalent of the Abrigo limestone of Bisbee, which has a thickness of 770 feet. These two limestones are certainly comparable in thickness; and in the prevalence of chert; but the Washington mountain limestone is more massive and, apparently, non-fossiliferous, due, possibly, to more intense metamorphism; while the Abrigo limestone is definitely proved by its fossils to be of Middle Cambrian age. In each district this older limestone is followed by a second white quartzite; but this is only 8 ft. thick at Bisbee and fully 100 ft. on the eastern slope of Washington mountain. Above this quartzite, at Bisbee, come several thousand feet of limestone, including the Martin limestone (Devonian), 340 ft.; the Escabrosa limestone (Lower Carboniferous), 800 ft.; and the Naco limestone (Upper Carboniferous), 1,500 to 2,000 feet. These Upper Paleozoic limestones of Bisbee may, perhaps, be correlated tentatively with the Washington Camp section above the parting quartzite; and I have been inclined to regard the latter as a general equivalent of the Harding sandstone in Colorado.[2] The heavy beds of chert in the middle part of the Washington Camp section appear to be wanting at Bisbee.

From the northwest border of the area of sedimentary rocks at least three great dikes of granite extend southward along the strike of the limestone. The most easterly dike, fully 100 ft. wide, forms the hanging-wall of the upper ore-body in the Pride of the West mine, and is separated by several hundred feet of chert and limestone from the second dike, which is proved by a cross-cut tunnel to be over 150 ft. wide. These two dikes converge southward and become one. The united dike can be traced across Double Standard gulch, passing west of the Holland mine; and it probably continues until it crosses the southern border and rejoins the main body of granite on the Belmont claim or the Lead King claim. The second dike, on the eastern slope of Washington mountain, is separated by a broad band of blue crystalline limestone and the parting quartzite from the third dike, which is at least 100 ft. wide, but appears to die out southward before reaching Double Standard

[2] *Folio* 7, United States Geological Survey.

gulch. Above this dike, the very massive crystalline limestone, with innumerable lines and lenses, but no heavy beds, of chert, extends to the summit and to the contact with the basal quartzite on the west slope.

In further comparison with the Bisbee district, it may be noted that the garnet ledge is more prominently developed than at Bisbee and that faulting is relatively unimportant at Washington Camp, so that there appears, in general, to be little difficulty in tracing a particular horizon from end to end of the sedimentary island or inclusion in the granite.

The granite varies from a normal biotite granite to a well characterized granodiorite, with dikes, also, of a highly acid, aplitic variety. The porphyry seems to show a similar range in composition, and occurs chiefly, at least, as dikes, cutting both the granite and the sedimentary rocks, although, probably, essentially contemporaneous with the former.

The metamorphic influence of the enclosing and intrusive acid igneous rocks is seen not only in the crystallization of the limestone to form marble, and of the chert bands to form quartzite, but also, and very strikingly, in the development in the less pure layers of the limestone of enormous bodies of green garnet (grossularite), and other secondary silicate minerals. The original limestone may safely be assumed to have contained silica, clay and iron oxide as the chief impurities; and from the more impure beds of limestone, during the process of metamorphism, the garnet-zones have been developed. These zones are commonly from 50 to 100 ft. or more in breadth; and they are found not only along the limestone-granite contacts, but also running in a north-south direction through the middle of the limestone remote from the granite, wherever, we may suppose, the original composition of the limestone favored their development, and chiefly along lines passing longitudinally through the Pride of the West, Holland, Double Standard and Annie belts of claims. The garnet rock, again, is not a constant feature of the contact, its absence at the north end of the district, on the eastern border and across a part of the south end, as also, in general, along the granite dikes, being especially noteworthy; but it is, apparently, developed only where the limestone was sufficiently impure to furnish in both quality and quantity the material required for the

formation of the garnet and related minerals. This selective relation is particularly obvious at the south end, where the contact cuts squarely across the strike of the limestone and the garnet-zone is developed only on the less pure beds of limestone. It is a very significant fact, in this connection, or in its bearing upon the origin of the garnet-zone, that along that part of the western border of the district where the basal quartzite intervenes between the granite and limestone, the garnet-zone is found between the quartzite and limestone, and not along the contact of the quartzite and granite.

The granitic rocks not only completely surround the sedimentaries, but, at some depth, they must underlie them, so that a vertical shaft at any point would, eventually, pass out of the limestone into the granite; and it is altogether reasonable to suppose that this lower contact, at least equally with the lateral contacts, is characterized by the garnet-zone.

The fact that the metamorphism of the sedimentary rocks is not confined to the borders, but is, in general, somewhat uniform over the entire area, varying only with the original composition of the limestone, and the absence, at most points, of a fine-grained or compact border in the granite itself, show not only that these rocks were very deep-seated at the time of the intrusion of the granite, but also, apparently, that the granite underlies the limestone now at no very great depth; although the Westinghouse shaft, on the extreme eastern margin of the limestone, has failed to reach the bottom at a depth of 650 feet.

Ore-Deposits.

Although having, in general, more or less the forms of veins, the ore-deposits are not, to any important extent, true veins; but are better classed as substitution deposits or replacements in the limestone. Among their more striking characteristics are the following:—

(1) They are entirely confined to the sedimentary rocks, and chiefly to the limestone, and have not been observed in any instance to extend never so slightly into the surrounding granite. This seems to force upon us the conclusion that the ores have not been derived from the granitic rocks, and have not. therefore, come from a great depth in the earth.

(2) Save where the contact is transgressive, they correspond closely, but not always exactly, with the limestone in dip and strike, and are at all points clearly to be recognized as replacements of the limestone.

(3) Where not accompanying the limestone-granite contact, they usually occur along the contact of the limestone with a principal bed of chert.

(4) They are, in general, very intimately associated with the garnetiferous zones, which undoubtedly represent what were originally exceptionally impure members of the limestone series. This association is so constant that the garnet has come to be recognized as a fairly reliable indication of the occurrence of the ores; and the garnet rock and the ores are often very intimately commingled, the garnet forming in most cases the principal gangue of the metalliferous minerals or ores.

(5) The ore-body accompanying a contact garnet-zone is always on the inside of the zone, that is, between the main body of the garnet ledge and the limestone, and not between the garnet ledge and the granite.

The ores include, chiefly, chalcopyrite and sphalerite, with, at the present time, very subordinate amounts of galena. Secondary ores are relatively very unimportant, and are now pretty well worked out. The oxidized copper-ores, including cuprite, the carbonates and chrysocolla, occur but sparingly and the secondary sulphides (bornite and chalcocite) are rarely seen. Although the copper-ore (chalcopyrite) ranks first in value at the present time, the zinc-ore (sphalerite) predominates in the deposits, tending to become relatively more important with depth; and an important output of zinc would seem to be among the possibilities for this district.

Metamorphism of the Limestone and Chert.

The crystallization of the purer phases of the limestone to form white to gray saccharoidal marbles and of the chert (in part) to form non-clastic quartzite are normal phenomena, demanding no special discussion. In part, however, the metamorphism of the chert has gone far beyond the degree here indicated. Thus, in the southwestern part of the field, on the Lead King and Belmont claims, bordering, but not penetrating, the granite, is a compact body of coarsely crystalline quartz

fully 100 ft. wide and extending, northward, in the direction of the strike and away from the granite, at least 300 ft. and possibly much farther. In large part this body is essentially structureless, consisting of massive, vitreous quartz; but enclosing, also, many more or less distinct crystals of quartz ranging in size up to at least 2 ft. in length and 5 in. in diameter, and occurring to a considerable extent in radiate groups. A shaft sunk 20 ft. into this mass disclosed nothing but pure quartz in a plexus of gigantic crystals. The outcrops in this part of the field are less continuous than could be desired; but the facts clearly indicate that this remarkable body of nearly pure crystalline quartz is not in any sense a vein, or a pegmatitic phase of the granite; but rather that it marks an extreme degree of metamorphism of a broad band of chert, the quartz being in the line of strike of such a chert horizon and seeming to grade longitudinally into it. Although an extreme, it is by no means an exceptional or unparalleled phase of the metamorphism, except, perhaps, in the magnitude of the resulting body of crystalline quartz; for coarsely crystalline quartz, sometimes in stellate groups, is a constantly recurring feature of the garnet-zones and ore-bodies; and it is probable that a detailed study of other chert bands in the vicinity of the granite would show that a gradation from the normal to the most highly-metamorphic forms of the chert is a general fact. Unfortunately, no economic interest attaches to the chert; and hence exploitation has added but little to our knowledge of its occurrence.

No correspondingly coarse crystallization of the limestone, on a large scale, has been noted; although, near the igneous contacts, and in the garnet-zones, it is commonly distinctly sparry, with cleavage faces of calcite 1 to several inches across. The chief interest of the metamorphism of the limestone is found, of course, in the secondary minerals; among which the pale yellowish or brownish-green lime-alumina garnet (grossularite) largely predominates, in finely to coarsely crystalline massive aggregates. The form is dodecahedral, and the individual crystals rarely exceed 2 in., and are commonly less than 0.25 in. in diameter. Associated with the garnet, in some parts of the field, is more or less epidote in slender, green prisms, with, possibly, some vesuvianite and various forms of amphibole, including actinolite and tremolite, the latter being

most abundant and often very intimately associated with the ores. Quartz, in coarse and irregular masses, is usually, as previously noted, rather a prominent feature of the garnet ledge, which, because of the hard and resistant character of its component minerals, forms bold and rugged outcrops, made, in detail, more rugged by the solution of the included sparry calcite and the weathering out of the ores. The crystalline iron-ores (magnetite, etc.), and the jasperoid forms of silica often associated with the garnet-zones of other districts are practically wanting in Washington Camp.

A rather specially interesting phase of the metamorphism of the limestone, though not as yet identified as a feature of the garnet ledge or the ore-bodies, is massive lime-silicate or wollastonite occurring commonly as a reaction-zone, bordering layers and nodules of chert in those portions of the cherty limestone nearest the granite, or within several hundred feet of the contact. The relations are very clear, the chert masses, often with frayed and disintegrated margins, being separated from the enclosing crystalline limestone (white marble) by zones 1 to several inches broad of the white and massive wollastonite, which, like the chert, is left in high relief on the weathered surface of the limestone. That the silica of the chert has replaced the carbon dioxide of the limestone is obvious.

The geologic interest of the metamorphism of the limestone centers in the source of the materials of the garnet and other secondary silicates. Although some recent writers have regarded the garnet-zones as intrusive igneous masses, or, possibly, as differentiation-products of the granite magma, the general consensus of opinion at the present time is that they are normal products of the contact-metamorphism of the limestone. No other view can be made to fit the facts of Washington Camp; and the question of vital interest is as to whether the limestone has furnished all or only a part of the ingredients of the garnet and other silicates, the necessary elements being approximately the same for them all. It is a significant fact that they are practically all lime-silicates; and apparently no one accepting the metamorphic theory doubts that the lime is wholly indigenous, that is, was furnished exclusively by the limestone. All the other required elements are normal im-

purities of limestone, including silica, alumina, magnesia and iron. The first two, with a little iron, suffice for garnet and epidote; and the addition of the magnesia makes the amphiboles a possibility. It is certainly a very exceptional limestone which does not contain the small amount of magnesia which this case calls for; and surely we have no need and no warrant to go outside of the limestone for such a normal, abundant and stable or insoluble impurity as alumina. The *onus probandi* clearly rests upon those who hold to the contrary view. Similarly, ferrous carbonate, not to mention the oxides and sulphides of iron, is a nearly universal constituent of limestones and a ready source of iron for the metamorphic ferruginous silicates, as well as for magnetite and sparry siderite.

Finally, silica, including free silica, both clastic and organic, and the combined silica of kaolin and other silicates, is, perhaps, the most important of all the non-essential elements of limestone. The ratio of silica to alumina in kaolin is less than in grossularite; but original free silica may easily make good the difference; and any excess of lime may or may not be eliminated by solution. The sufficiency of the free silica is indicated by the fact that in many analyses of limestones not visibly siliceous the total silica is far in excess of the amount required to form kaolin with the alumina. The averages of 42 analyses of limestones made in the laboratory of the United States Geological Survey,[3] including all those for which both the silica and alumina are given separately, are: SiO_2, 8.514, and Al_2O_3, 1.077 per cent., the ratio being very nearly 8:1.

Analyses of unaltered limestone are, of course, devoid of special significance in this connection, unless it can be shown that they represent closely adjacent portions of the same beds which have, locally, suffered metamorphism by silication. Limestones, more than most other kinds of sediment, are, in successive beds, subject to marked and abrupt changes of chemical composition, due to fluctuations in the proportions of the normal (organic) and the accessory (organic, clastic and chemical) constituents; and gradations into beds of chert, shale and even sandstone are not uncommon.

In view of these considerations, further argument might almost be deemed superfluous, at least as regards the adequacy

[3] *Bulletin* 228, United States Geological Survey.

of the limestone, considered as a source of the raw materials of the contact minerals. But some of the arguments based upon the structural relations of the limestone are also peculiarly cogent. For instance, the garnet-zone is, as previously noted, by no means a constant accompaniment of the granite-limestone contact; and in strength and persistence it obviously varies inversely as the purity of the limestone, being very weak or wholly wanting where the purer beds of limestone, the typical white or light gray marbles, meet the granite. This selective relation is very noticeable across the ends, and especially the broad southern end, of the limestone island, where the granite contacts successive beds of limestone of varying composition, and fails to develop a garnet-zone wherever the limestone is of notable purity. Besides the variable and intermittent character of the garnet-zone along the contact, we must take cognizance of the very persistent garnet-zones which, disregarding the granite contact, follow each a particular bed or horizon of impure limestone longitudinally through the district; and of special interest and significance among these is the garnet-zone at the base of the limestone, in the siliceous and argillaceous beds of passage between the basal quartzite and the limestone and separated by the quartzite, from 100 to 200 ft. thick, from the western granite.

Among those who accept the metamorphic origin of the garnet-zones of granite-limestone contacts, Professor Kemp is the foremost exponent of the view that the granite has contributed not only the heat or thermal energy, but also, in large part, the material, required for the formation of the garnet and related silicates. Apparently, Professor Kemp would look to the granite or acid plutonic for everything needful, except, perhaps, the lime; although it may be noted that the plutonic rock is, in general, rich in lime as well as alumina and the transfer of the former base would be the simpler chemical problem. However, the lime is not needed; and in my opinion it has not been proved that we need look beyond the sedimentaries for any of the raw materials of the garnet-zone. To simplify the phraseology and at the same time to emphasize the vital contrast of the two explanations of the garnet-zone now under consideration; we may restrict the term "metamorphic" to the theory which derives all the material from the

limestone and refers to the granite only for the agents—heat and, possibly, some water; and designate as "metasomatic" the theory which derives an important and essential part of the material, as well as the agents, from the granite.

Except where the limestone is very impure, the lime will naturally be in excess of the amount required to form the garnet and other secondary lime-silicates; but that this is in no sense a bar to the metamorphic theory must be obvious when we consider the possibility of disposing of the excess by either contemporaneous or subsequent solution or re-crystallization. An instructive illustration, on a minor scale, is offered by the writer's observations on the calcareous Lower Cambrian slates of the Boston Basin. In this instance the calcareous element assumed originally the form of calcareous concretions or clay stones; and when, in later Paleozoic times, the strata were invaded by the granitic series and suffered metamorphism, the outer part of each calcareous concretion became a shell of impure epidote. In many cases the silica and alumina within this shell have been exhausted in the formation of the epidote and the residuary calcium carbonate has re-crystallized, forming a core of white marble in the epidotized calcareous concretions of a red slate.

Regarding the granite as an important or, possibly, principal source of the materials of the garnet-zone, as we may for the sake of the argument, gives the contact-relations and character of the granite special significance and interest, since it is not easily credible that the granite might transfer to the limestone a large part of the material of the garnet-zone and still remain entirely normal, giving no sign of its loss. As a matter of fact, both the granite and porphyry, so far as can be determined by macroscopic observations, are unchanged in texture and composition and entirely normal on and near the sharply defined line of contact. In other words, the granite shows no reaction-zone, and there is absolutely nothing to suggest the leaching, depletion or mineralization of either formation by, or at the expense of, the other. These statements are applicable alike to the main body of the granite and to the granite dikes.

If the silica and alumina have been derived from the granite and the limestone has furnished only the lime, magnesia and

iron, the garnet-zone should be a constant feature of the contact; or at least there is no apparent reason why it should fail, as it does, just where silica and alumina are wanting in the limestone. Again, the metasomatic theory affords absolutely no explanation of the essentially similar and equally strong garnet-zones developed independently of the granite contacts, in the limestone or between the limestone and the basal quartzite; for surely we cannot suppose that material in liquid or gaseous solution would pass through hundreds of feet of solid limestone or quartzite to react with the limestone of certain definite and narrow horizons.

Professor Kemp has minimized the normal ground-water, of oceanic and meteoric origin, and maximized the magmatic water emanating from plutonic and intrusive magmas before and during refrigeration, as regards both volume and geological efficiency, and especially as regards their efficiency in the formation of veins and ore-deposits. The only definite and positive indication that the magmatic water is abundant is afforded by the copious exhalations of steam accompanying volcanic eruptions. But the argument that this is all, or even chiefly, magmatic water is far from conclusive. Its deposits certainly do not indicate it. A distinguishing feature of magmatic water is supposed to be its heavy burden of dissolved elements, which, combined to form various mineral species, must be left behind, on or in the lava, as the water escapes into the atmosphere. Except, perhaps, in, or in the immediate vicinity of, vents of long-continued solfataric activity, these deposits are usually conspicuous by their absence. The water promotes the liquidity of the lava, and thus, in a sense, holds in solution the entire body of the magma, and, although diminishing with the pressure, like the gases dissolved in molten metals, it manifests no marked tendency to escape in advance of the general refrigeration of the magma; and then, in general, it leaves behind no deposit other than the normal lava.

The argument for the sufficiency of magmatic water requires us to assume that below the superficial, shallow and wet zone of the vadose circulation in the earth's crust is a deep and relatively arid or anhydrous zone, the upper part of which has been discovered by numerous mines and borings, and below

that, in the plutonic regions, where magmas are developed, a third zone which, like the vadose, is highly hydrated, but the water of which is original or primitive, and has never formed a part of the hydrosphere. The intermediate, relatively dry zone, comprising the main body of the earth's crust, is composed, for an average thickness to be measured by miles, of sedimentary rocks, which must have once been in a state of supersaturation, but which have suffered extensive dehydration under the combined influence of long-continued heat and pressure. How it is that the water of the plutonic zone, exposed for an immensely longer time to far higher temperature and pressure, has escaped expulsion has not been explained. Further, it is virtually asserted that the volcanic chimney belongs to that bad class which will not "draw"; in other words, that the subterranean chimney does not create an in-draught of the ground-water analogous to the in-draught of air to a subaërial chimney. This anomaly, if true, also awaits explanation.

For the magma, the conditions are dominantly thermal; but for the resultant lava they are, or soon become, dominantly aqueous. The component minerals then prove to be more or less unstable compounds and are subject to alteration by the in-drawn ground-water, the solvent and decomposing action of which is promoted, rather than retarded, by the high temperature still prevailing. In other words, solfataric waters, by which alone important deposits are made within the range of observation, are probably not, chiefly, magmatic waters struggling up from plutonic depths; but, rather, they are to be regarded as marking the first and most vigorous attack of the normal ground-water upon the intrusive and effusive igneous rocks, and hence as positive proof that the chimney does draw at this stage, if not earlier.

In any speculation as to the volume of water set free by the freezing of a magma under plutonic conditions, it is important not to forget the shrinkage due to crystallization and cooling, or that the liberated water, though above the critical temperature, may yet have the density of the liquid, or that there exists a real affinity between this water and the magma residuum, as so clearly proved by the phenomena of pegmatite. It is the excess water, if there be any, that concerns us now; and its nat-

ural avenue of escape, it would seem, should be upward, rather than lateral.

The picture of a copious exudation of magmatic water which, reinforced by various mineralizers and overladen with a large variety of elements, actively invades and alters the enclosing terranes by metamorphic and metasomatic processes, is not easily visualized, in view of the plain, every-day facts of the case. In the vicinity of Boston, and extending throughout eastern Massachusetts, the coastal district of New England and the maritime provinces, are hundreds of miles of contact of granitic rocks, not to mention a vast net-work of acid and basic dikes, intrusive in Cambrian and other early Paleozoic sediments. These sediments exhibit various degrees and kinds of metamorphism; but very seldom indeed do we find in them elements which may not fairly be regarded as original. Fluorite and other minerals regarded as specially indicative of the presence and agency of the so-called mineralizers are found chiefly in the igneous rocks and have not migrated into the sediments. Apparently, heat is the one important contribution of the igneous rocks; and the normal ground-water stimulated or energized by this heat and acting on the original elements of the sediments has done the rest. Even quartz-veins and segregations, excepting those of pegmatitic origin, are comparatively rare accompaniments of the plutonic contacts of this region, and where occurring may usually be proved to antedate (as in the case of the auriferous veins of Nova Scotia) or postdate the development of the contact.

Especially difficult of visualization is the picture of the magmatic water gushing forth in so great volume that, merely by the deposition of its excess load, it may build a garnet-zone 100 ft. thick, equal to 100 cu. ft. of garnet and the emission of many thousand cubic feet of water for every square foot of the contact. The magma must, indeed, be highly hydrated to meet such a demand, and yet it is now of strictly normal character up to the sharply defined contact.

The development of the garnet-zone, whether by metamorphic or by metasomatic process, must have been centripetal with reference to the limestone, at least if we are to look to the limestone for the lime; necessitating, according to the metasomatic theory, the transfer of the silica and alumina and

other imported elements required for the inner part of the zone through the outer part. Also, the refrigeration or crystallization of the magma to form the granite must have proceeded centripetally or away from the contact, thus opposing a barrier of steadily increasing thickness to the emission of the magmatic water. In other words, the water liberated by the crystallization of the magma is forced inward, where it is needed to maintain the fluidity of the magma residuum.[4]

Origin and Relations of the Ore-Deposits.

The ore-deposits of this district clearly belong to certain more or less well-defined zones in the limestone, which may or may not follow granite-limestone contacts, but which are in general characterized by a more or less marked development of the garnet ledge. The relations of the ore-bodies to the garnet-zones are very intimate and irregular, and the garnet and other secondary silicates, together with a limited amount of quartz and sparry calcite, constitute the normal gangue of the ores. But although we may regard the garnet ledge as in a general way favorable to the occurrence of ore, some important ore-bodies are devoid of garnet; and the garnet-zones are at some points devoid of ore, or the ore occurrences are very limited and sporadic. Where associated with garnet-zones following the granite-limestone contact, the normal position of the ore, as previously stated, is, clearly, on the inner margin of the zone, facing the limestone and not the granite. The ore-bodies are, practically, never vein-like in form or structure; and they are devoid of true walls, since they clearly antedate all shearing and fracturing of the formation. The contact of the ores, alike with the limestone and the garnet, is often sharply defined, but always highly irregular; and in the association or grouping of the ores there is nothing even remotely suggestive of crustification, banding or comb-structure, or deposition in open spaces of any kind. Obviously enough, the ores, as we now have them, are due to a metasomatic impregnation and replacement of the limestone against and in the massive garnet ledge; and the questions of special geological interest are, whence? and how?

[4] Origin of Pegmatite, *American Geologist*, xix., 170.

That is, what is the original source of the ores? and how were they concentrated?

We cannot avoid the conclusion that the ores have come from either the limestone or the granite. Nowhere in the district has the slightest trace of ore been found in the granite. The ore rarely contacts the granite, and then only sparingly or sporadically, its normal position being between the garnet ledge and the limestone and irregularly impregnating both. The most persistent and strongest ore-bodies, again, are associated with the non-contact garnet-zones, which are, in part, far removed from the nearest border of the granite. In no instance has it appeared possible to correlate the ore-bodies with antecedent fissures, which might, conceivably, have served as channels of supply from underlying granite. The demonstrated faults of the district are clearly newer than the ores; and the latter sometimes exhibit beautiful slickensides where traversed by shear-planes and displacements.

The main body of the limestone, apart from the garnet-zones and ore-deposits, is, apparently, as barren of ore as the granite; and accepting either of these formations as the source of the ore forces the conclusion that the processes of segregation and concentration have been singularly complete; although it is, of course, possible that refined analysis would prove the presence of zinc and copper where none are apparent to the eye. The plain indications are that during the metamorphism of impure and, presumably, metalliferous beds of the limestone to form the garnet-zones, the metallic sulphides contained in these beds, and, possibly, in large volumes of the adjacent strata, were segregated by metasomatic process along the common boundary of the garnet-zone and the limestone.

As previously noted, Washington Camp is undoubtedly an outlier, isolated by igneous intrusion and erosion, of the great series of Paleozoic limestones in which are found a very large proportion of the ore-deposits of the Rocky mountain region and the Pacific coast, as well as the widespread and rich zinc- and lead-deposits of the Mississippi valley, the last-mentioned district having been, from the beginning of Paleozoic time, remarkably free from every phase of vulcanism and having suffered as little deformation as any part of the continent.

It appears difficult, in view of these considerations, to find

any warrant for doubting that this great limestone series, or some part of it, is normally and originally metalliferous; or that, stimulated by intense and long-continued igneous and metamorphic agency (which was not required in the Mississippi valley), the circulation of the normal ground-water has proved equal to a more or less complete concentration of the metallic contents of the limestone.

Structural Details.

It is proposed to give here some local observations, which, although not conveniently included in the foregoing discussion, are of interest in their bearing upon the general theory of the district.

West Contact.—Beginning at the north end, a shaft on the Kansas claim, 150 ft. from the limestone-quartzite contact and 100 ft. deep to water-level, with about 200 ft. of drifting, shows mainly pyrite, with subordinate chalcopyrite, galena and blende and abundant quartz gangue. The main ore-body is vein-like in form, but without walls, and clearly a replacement in the limestone, with many isolated bunches or pockets of ore from 3 in. to 3 ft. or more in diameter and usually parallel to the main ore-body and the bedding of the limestone. The garnet ledge is not developed here; but a feature of special mineralogical interest is found in the pseudomorphic cavities due to the oxidation of the pyrite.

Next, south of this, on the New York claim, where the garnet ledge is also wanting, a shaft 205 ft. deep has developed, at a distance from the quartzite-contact, one large and one smaller irregular ore-body, carrying above the water-level good values in lead and silver.

Between the New York and Maine claims the quartzite is broken or sharply flexed, being offset to the west several hundred feet, on the northern slope of Washington mountain; and the garnet ledge is developed on the blending contact of the quartzite and limestone. Mingled with and following the garnet is the ore-impregnated limestone. All along this western contact the reaction-zones of wollastonite are a nearly constant accompaniment of the chert lenses and nodules in the limestone; but this feature gradually dies out as we recede from the granite.

On the Ella claim, crossing the upper western slope of Washington mountain, the basal quartzite is well developed, with a breadth of from 100 to 200 ft.; and, as before, it separates the garnet ledge, about 50 ft. wide, from the granite. The ore, which runs largely to black sphalerite, in part admirably crystallized, occurs chiefly in the inner part of the garnet-zone, forming an irregular, weak or fragmentary body, accompanied by some striking stellate groups of quartz crystals.

On the contact claim, crossing the hill at the head of Bonanza gulch, this section is repeated from the granite through the quartzite and the ore-bearing garnet-zone to the limestone. But, although the garnet-zone is strong, the ore is weak and does not form continuous bodies. These conditions recur, also, on the Montezuma claim, which marks the southwest corner of the district; but the basal quartzite is here distinctly ferruginous and carries low values in gold.

On the Lead King claim, at the extreme southern end of the district, the granite is well exposed in two tunnels driven to cut the contact. Although of a highly acid and, in the main, essentially normal character, it is in part, also, more or less pyritiferous, the pyrite occurring chiefly, but not wholly, in the seams. No other instance of mineralization of the granite has been observed.

Eastern Contact.—Toward the southern end of this contact is the chief occurrence of porphyry, which appears to be somewhat later than the granite and of rather more acid character; but, so far as observed, does not differ from the granite in its relations to the limestone and the ore-bodies. The eastern garnet-zone follows the contact somewhat continuously across the San Antonio and Duquesne claims to the Bonanza claim, on which is located the Westinghouse shaft, 650 ft. deep. The shaft starts in the porphyry; but all the lower part is in coarsely crystalline white limestone, and the bottom is said to be 65 ft. from the porphyry, proving that the contact overhangs the limestone a little. Farther north along this contact, the garnet-zone and ore-bodies are wanting, and we pass abruptly from the granite or porphyry to the gray to white marble, which is uninterrupted for a breadth of 1,000 feet.

North of Washington Post Office the contact is easily traced, and where it is crossed by the road for the last time it is well

exposed in a cutting, showing normal granite against white crystalline limestone, with no signs of a garnet-zone, although a prospect hole shows a thin line of ore, while a little farther north a line of prospect holes shows that the contact is there more heavily mineralized.

Central Ore-Zones.—These zones practically begin with the Pride of the West claim, in the latitude of Washington Post Office. This property, which produced a large amount of oxidized lead-silver ores above the water-level 25 years ago, embraces two ore horizons from 10 to 20 ft. thick, separated by from 20 to 50 ft. of limestone, and dipping west 33° beneath the eastern dike of granite, which forms the hanging-wall of the western ore-body, and is, in turn, overlain by a heavy bed of chert. The granite seems to conform with the bedding of the limestone, but the under surface of the granite or hanging-wall of the ore is very plane, more or less coated with garnet, as a rule, and beautifully slickensided. This is, evidently, a fault-plane which has, apparently, cut out the main part of the garnet-zone.

In their southward extension to the next ridge, these ore-bodies leave the granite dike, and are thrown eastward, with the great bed of chert, 500, and possibly nearly 1,000 ft., by a transverse flexure or fault. Beyond this displacement they are continued, still on the east side of the chert, in the similar and parallel ore-bodies of the Smuggler claim. About 300 ft. farther east is the parallel ore-zone, from 10 to 15 ft. thick, of the Texas claim, which has not been identified on the Pride of the West ground. The Texas ore is chiefly blende, with walls of limestone; and the garnet-zone is not prominently developed north of Double Standard gulch; but we have now, in addition to the displaced continuation of the double Pride of the West ore-zone on the Smuggler claim, and still holding the same relation to the great bed of chert, though now widely separated from the granite dike, the parallel ore-zone of the Texas claim.

A series of prospect holes extending from the Smuggler workings shows very clearly that the dual ore-body is here flexed backward, and, pinched and dragged out, trends directly toward the tunnel on the Double Standard claim. In other words, we have here a compensating displacement, the dual

ore-body being thrown from the south end of the Pride of the West claim eastward into the Smuggler claim, and then westward into the Double Standard claim, where both members, with their normal characters, have been cut by the Double Standard tunnel. The fact that the granite dike is not thrown with the chert-bed and ore-zones indicates that the displacements, in this case, antedate the intrusion of the granite; but that there has been some movement, at least, along these breaks subsequently to the formation of the ore is made very clear by certain phenomena brought to light in the Double Standard workings. The tunnel cuts the ore-zones just at the break, where they are regaining the normal north-south strike; and a winze was sunk at this critical point on the eastern zone. That this winze is directly in the crushing and disturbance accompanying the great fault is evident from the highly broken and cavernous condition of the ground. That the movement to which this broken and open structure is due was subsequent to the metamorphism of the limestone and the formation of the ore-bodies is unquestionable, since both are involved in the crush breccia. But that this movement was also accompanied or followed by conditions favorable to ore-deposition is proved by druses of pyrite, sphalerite, quartz, etc.; and especially by the occurrence of a cavity several feet in diameter lined with a reniform layer or crust of native arsenic 1 to several inches thick. This occurrence of native arsenic, which has been described by Dr. C. H. Warren,[5] undoubtedly finds its best explanation in thermal waters rising along the fault, that is, in something analogous to fumarole action.

On the ridge which we have now reached, separating Double Standard and Bonanza gulches, a section from east to west across the ore-zones shows: (1) the displaced extension of the ore-zone first recognized on the Texas claim; (2) a strong and typical garnet-zone; (3) the double ore-zone of the Pride of the West, Smuggler and Double Standard claims; (4) the massive chert-formation everywhere overlying the dual ore-zone; (5) an unmeasured thickness of crystalline, gray limestone; (6) the Holland ore-zone, not previously recognized, with its garnet-zone. All of these various horizons are recognizable again

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[5] *American Journal of Science*, 16, pp. 337–339 (1903).

south of Bonanza gulch, in the Annie, Mary Jane and other claims; and still farther south on the Empire and Belmont claims, the garnet-zones, if not the ore-zones, appear to gain in strength as we approach the granite.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Electrolytic Assay of Lead and Copper.

BY GEORGE A. GUESS, SILVERTON, COLO.

(British Columbia Meeting, July, 1905.)

THE increasing demand for greater speed and more accuracy, in making daily assays of ores and products from mills treating material containing but very small quantities of lead and copper, has caused the older analytical methods to be supplanted by new ones devised to meet the needs of modern work.

For "control" work in copper analyses, I had, previous to the present equipment, introduced in my laboratory the ordinary electrolytic method, using hollow cylindrical electrodes, and with these I began a series of experiments in determining the lead-content of daily mill-samples and controls. The results, proving accurate and satisfactory, I then devised, with Mr. H. E. T. Haultain, a cheaper electrode than the ordinary jacket electrode, which costs from $15 to $20,—the expense of the older form making the installation of many units very costly.

The form of cathode finally adopted as the most satisfactory, shown in Fig. 1, is cut from 0.001-in. platinum foil. It is 12.5 cm. long, and is divided into a blade 4 cm. wide and 6.25 cm. long, and a tongue 0.7 cm. wide and 6.25 long, the immersion area being 50 sq. cm. and weight 1.5 grams. The blade is first sand-blasted and then corrugated lengthwise, in order to impart the necessary rigidity. Strips of platinum foil 0.001 in. thick, 12.5 cm. long and 0.5 cm. wide, having a median corrugation, form the anodes. Three electrodes are used in each cell; one anode in the middle and one cathode on each side of the anode. These electrodes are connected to slotted aluminum terminals, in which they are held by contact pressure. The terminals are $\frac{5}{8}$-in. rods, projecting 2 in. horizontally in front of the wall of the cabinet; at the back the middle electrode (anode) is connected with one pole of the current, and the two outer ones (cathodes) with the other pole.

The present equipment in the laboratory consists of two cabinets of 30 cells each, one used for lead and the other for copper-determinations. Each cabinet is individually wired in series, but both are connected in multiple and receive a current of 130 volts, which is controlled by enameled field-rheostats, one for each cabinet. (See Fig. 2.) Formerly, lamps were used to furnish the resistance. One voltmeter and one ammeter reading to 0.02 amperes is sufficient for both cabinets.

Exclusive of wiring at and from the power-house, the cost of installation, made by Mr. Haultain and myself, was much less than $200. The platinum, ordered in sheets, was cut, sand-blasted and corrugated. The aluminum was purchased in ingots and cast into terminals. A carpenter took three days to make the cabinets. With this equipment I make an average of 45 lead- and 50 copper-determinations daily, besides attend- to other work of the office.

I am not aware that any other electrolytic method is in practical daily use for the estimation of lead. In devising my method I have referred to the published articles of various chemists, and to the books of Classen, Neumann and Smith bearing on the subject. Briefly, the method is as follows:

The ore, weighed into a tall battery-beaker of 100-cc. capacity, is digested with 10 cc. of nitric acid. The lead sulphate formed is readily dissolved after boiling by the addition to the beaker of from 10 to 20 cc. of a saturated solution of ammonium nitrate containing 20 per cent. of free ammonia. After solution the beaker is nearly filled with water, and from 10 to 20 cc. of nitric acid added. The solution is now ready for electrolysis. A wide range of current strength is permissible, but from 1.5 to 2 amperes is most satisfactory; this amount keeps the solution sufficiently hot during the electrolysis. At the end of two hours, the lead is completely deposited in the form of peroxide on the anode. The anode is then removed, washed in water and in alcohol, ignited and weighed. The theoretical factor is 0.866; but in practice 0.855 is found to be more accurate; probably due, as Hollard says, to an excess of oxygen in the peroxide.

The accuracy of this method ranks with that of carefully made electrolytic coppers, and its great advantage is the small amount of the chemist's time required. In the presence of

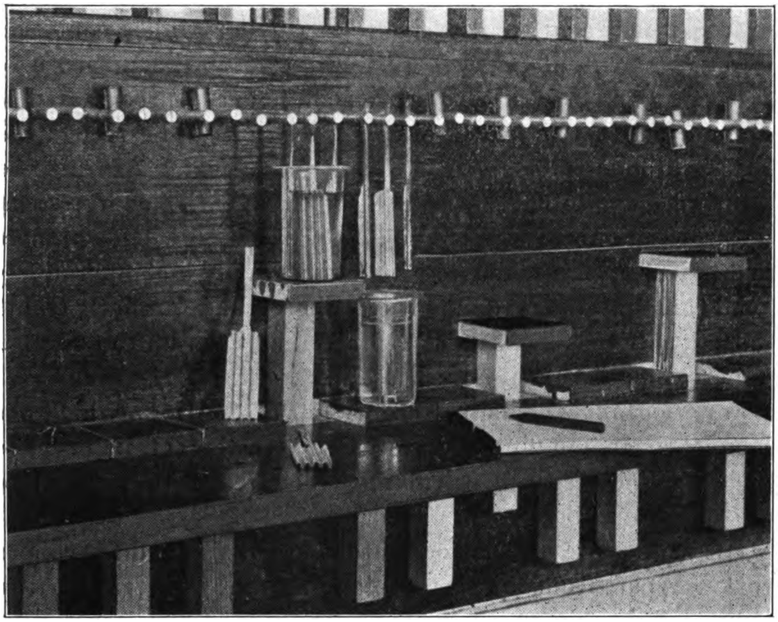

FIG. 1.—ANODES, CATHODES AND TERMINAL CONNECTIONS.

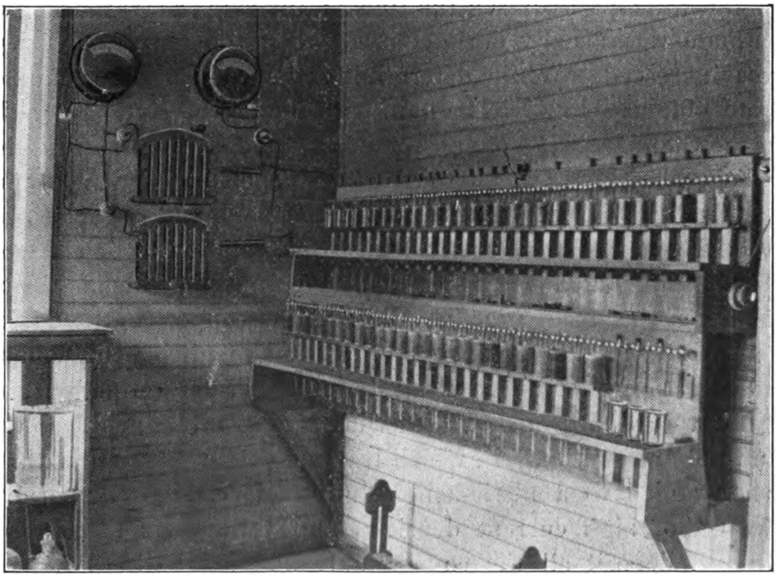

FIG. 2.—ELECTROLYTIC CABINET SHOWING RHEOSTATS, VOLTMETER AND AMMETER.

manganese or antimony, it is necessary to have a large excess of free nitric acid in the electrolyte, under which condition neither element interferes. Bismuth, even in the presence of very large amounts of free nitric acid, is partly precipitated as bismuth oxide with the lead. Its presence can be recognized by a light-blue color given to the peroxide coat. Arsenic and tellurium have to be removed before electrolysis, for if present in large amounts they effectually prevent any deposition of lead. Unless the anode is sand-blasted, only a comparatively small amount of peroxide will adhere, but, properly sand-blasted, adherent deposits of 250 mg., and even up to 600 mg., of peroxide may be obtained in daily work.

For weighing the pulp I use weight of 855 mg., which has been christened a "plum," and multiples thereof, in order to avoid the necessity of calculating each result, the weight of peroxide found being called lead.

The same style of electrodes are eminently suited for copper work. Apart from the cost of platinum the great drawback in the use of the electrolytic method for copper-determination in daily work is the time required for the electrolysis, usually amounting to from 8 to 12 hours. Many substances were tried in the attempt to lessen the time of the copper assay, but the cathode was usually dark colored when the current density was increased. While determining the copper in a concentrate obtained by Mr. Haultain with the use of No. 4 hard oil of the Standard Oil Co. and retaining some of the grease, a peculiar glossy luster was noticed on the deposited copper. Some of this hard oil was treated with nitric acid, and the solution, freed from grease, was then added to the solution to be electrolyzed. The current was increased to 5 amperes, which is about 25 times the usual practice, and still the copper continued to come down bright. The preparation of this "nitro" compound called "dope," for use in electrolytic copper-determinations, is as follows:—hard oil is boiled with strong nitric acid, cooled and the grease removed, which leaves a deep-red solution that when added to a nitric-acid solution of copper will permit the use of high current densities and yet, under these conditions, deposit all the copper pure and bright in 3 hours. Moreover, arsenic and antimony, which interfere seriously in ordinary electrolytic precipitation of copper, do not contaminate

the deposit of copper, even if present in very large amounts. More than 3,000 copper-determinations have been made in this way, and experiments have also been made on smelter flue-dust and copper-dummies containing large amounts of arsenic and antimony. In these cases the results were always satisfactory.

The use of the oil in electrolytic work is as follows: The ore, weighed into tall battery-beakers of 100-cc. capacity, is digested with 7 cc. of nitric acid, and boiled until nitrous fumes have been expelled. About 2 cc. of dope, diluted with nitric acid, are added (or it may be added with the acid), the beaker filled with water and allowed to settle for a moment, it is then electrolyzed with a current of 1.5 amperes for 3 hours. The cathode must be sand-blasted, otherwise the copper is apt to fly off when it is ignited.

There should be no gassing whatever at the cathode during electrolysis. The cathodes frequently gas when the current is first turned on, but if turned off for a second and then on the gassing should cease. The cathode frequently gasses at the end of 3 hours, when the assay is finished.

Several different nitro-hydrocarbons have been tried instead of the dope in the 3-hour copper assay, and of these, di-nitro-alpha napthalene produces, with a little more care during electrolysis, results nearly equal to the dope.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Origin of Clinton Red Fossil-Ore in Lookout Mountain, Alabama.

BY WILLIAM M. BOWRON, CHATTANOOGA, TENN.

(British Columbia Meeting, July, 1905.)

THIRTY years ago, when I stood on the cliff of red fossil iron-ore, on Red mountain, Jefferson county, Ala., I asked what were the geological relations of this remarkable deposit. In reply I was told that it was a limestone colored and saturated by some unknown but wholly external influences, and that at a reasonable distance from the surface the color would disappear.

I could find no satisfactory explanation either of the nature of this wonderful external permeating influence, or of the cause of such a ferrous impregnation selecting this one particular bed of limestone, to the exclusion of the higher and lower beds of the same material which are not even stained.

I. THE PRESENT THEORY.

Referring to this subject, Dana says:[1]

> "The clays, clayey sandstones and limestones of the Clinton epoch, through New York and the Appalachians, show that the mud-flats and sand-banks, and hence the shallow seas of the coast region, still continued. . . . The beds of argillaceous iron-ore, which spread so widely through New York and some of the other States, south and west, could not have formed in an open sea, for clayey iron-deposits do not form under such circumstances. They are proof of extensive marshes, and, therefore, of land near the sea-level. The fragments of crinoids and shells found in these beds are evidence that they were, in part at least, salt-water marshes, and that the tides sometimes reached them."

At first, this explanation seemed satisfactory, but the more I studied the ore the less satisfying the explanation became.

1. In the ore itself I found associated with the small particles of rounded matter (now consisting of iron oxide in which organic structure, if ever present, has become lost, though the

[1] *Manual of Geology*, 2d ed., 1875, p. 231

general shape is often strongly suggestive of *foramenifera*, *ostracodæ*, and the minute calcareous organisms which have contributed their skeletons to the limestones of the world), an assortment of *brachiopoda* so varied as to give evidence of a large feeding-ground. These species, anchored when mature, feed on the minute life which, in turn, feeds on the sub-aqueous growth that is possible in shallow water only. Iron-water would have introduced conditions fatal to such plants and animals.

2. Apart from single shells, which might have been brought by tides or washed in over a circumscribing bar that would have rendered swamp-conditions possible, I found a fairly large colony of a *brachiopod*, which, like the mussels (*mytilus edulis*) that cluster round the dock-gates and posts of our seaports, had the habit of crowding in family groups till even the shells were distorted by such close proximity,—hence their specific name, *stricklandinia deformis*.

3. I found, also imbedded in the red ore, a portion of a reef-coral as pure and white as when secreted in the clear and well-aërated waters of the Paleozoic ocean.

4. On a base of a mud-parting I found the whirl of terminal "*cirri*" that form the root of one of those fixed *crinoids*, the bead-like joints of whose flexible stem are so familiar among the distinguishable remains that go to make up the bulk of the ore.

Dana says of the Upper Silurian:[2]

> "There was no evidence that the climate of America included frigid winds or seas. The living species in the waters between the parallels of 30° ond 45° were in part the same with, or closely related to, those that flourished between the parallels of 65° and 80°. From this life-thermometer we learn only of warm or temperate seas."

The foregoing evidence shows that there was a large and flourishing life-growth of the usual types common to warm shallow seas; that corals of types requiring free access of currents of sea-water were common; and, lastly, that very little difference in temperature existed between the parallels of 30° and 80°, a condition which can only be accounted for by an oceanic current of sufficient bulk and constancy to neutralize climatic differences.

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[2] *Op. cit.*, p. 253.

The whole argument is fatal to the swamp-theory. I saw this objection, and appealed for information to those whose opportunities to study the ore had been greater than my own; but I was told that nothing was known definitely about it. I then began to gather the evidence in the case and found, at the outset, that only one argument would lead anywhere, and that was "How was the ore formed in this particular place?" A general scheme involved too many unknown local quantities, which, if assumed instead of being "observed," might introduce error into the hypothesis.

I also carefully examined all geological publications on the subject that I was able to find.

The most interesting paper[3] includes a description of fossiliferous iron-ore from Rochester, N. Y., by J. S. Diller, which is specially valuable, since it shows the views held by geologists who have had exceptionally favorable opportunities for studying the whole evidence. Mr. Diller says in part:

"The ore is usually fossiliferous, as is specimen 52, and is sometimes called 'red fossil-ore.' At other times it is öolitic, and is referred to as the öolitic fossil-ore; also as the Clinton ore, on account of its age and place of best exposure. The fossils are chiefly broken *crinoids* and *bryozoa*.

"The rock is made up of flattish or elongated grains, many of which are fragments of shells, but when seen in the hand the specimens all appear to be oxide of iron. Under the microscope, however, these fossil fragments are, in most cases, found to be only partially made up of iron-ore. . . . Some of the grains look öolitic, but in a thin section, no concentric or radial arrangement, suggesting concretionary structure, was observed. In many other places, however, as shown by Smyth, the öolithic structure is well developed. . . . The silica (binding the grains together) is occasionally radial-fibrous and optically negative, like chalcedony.

"The fossiliferous and bedded character of this ore, and its extensive distribution, are altogether exceptional, so that its origin is a matter of much interest. James Hall regarded it as derived from pyrite, in part at least, through the action of thermal waters, but this view has long since given place to other hypotheses.

"The öolithic structure of the ore, as shown by Newberry, favors the view which regards the ore as an original deposit instead of a subsequent replacement of the limestone."

C. Willard Hayes has recently examined many of the Clinton iron-ore mines of Tennessee, Georgia and Alabama with special reference to data concerning the origin of the ore; and he

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[3] "Educational Series of Rock-Specimens Collected and Distributed by the U. S. Geological Survey," *Bulletin No.* 150, U. S. Geological Survey (1898).

reports that he has never found it passing into a non-ferruginous limestone. He also says: "While it is true that the proportion of iron to lime in the unweathered ore varies in some cases rather rapidly, it is quite as apt to vary along the strike as upon the dip, showing that the variation is original and not dependent upon the depth below the surface." His observations lead him to conclude, as did Newberry and Smyth, that the iron-ore is an original constituent of the bed, and not due to later replacement.

These statements though conclusive, as far as they go, only transfer the question further, leaving still unsolved the problem of the origin of the ore.

II. Personal Investigation.

For ten years or so I had daily opportunities of seeing about 10 freshly-mined cars of the lean ore from Inman, Tenn. I became interested in the fossils, and, among others, I collected the following from the ore:

Merista natida,	* *Diphyphyllum multicaulis,*
Stricklandinia deformis,	*Favosites favosus,*
Rhynchonella neglecta,	*Zaphrentis, various species,*
Pentamerus oblongus,	** *Fenestella Sp.? Near Stellatum,*
Strophomena rhomboidalis,	*Rensselaeria ovoides,*
Rhynchonella cuneata,	*Spirifer radiatus?*
Atrypa reticularis,	*Rhynchonella whitti,*
Choenetes Sp.?	*Dalmanites Sp.?*
Orthis elegantula,	*Calymene Blumenbachia,*
Orthis fissiplica,	*Platyostoma Sp.?*

* This is absolutely iron oxide, a colony of several square feet. Will the advocates of original deposition say that the coral was secreted as iron?

** This is pure white, is surrounded by red ore, and has no red particles mechanically held in its texture.

One peculiarity soon developed itself. In some of the leaner ore, and contrary to Mr. Hayes' experience, I found it in all gradations of iron-content, from absolutely pure limestone material to that in which the iron was of almost theoretical composition. Moreover, I took chips of very lean ore, and, omitting the usual laboratory crushing, I put a handful of the chips in a suitable vessel and left it for a week or so covered with dilute hydrochloric acid, which formed a supernatant iron solution

(subsequently decanted), and a mud. This mud was boiled with strong hydrochloric acid and potassium chlorate, which dissolved the alumina and left a greyish residue consisting mainly of silica, some of it being in the familiar gelatinous condition suggesting its having been present either as chalcedony or as a constituent of a silicate. On removing the silica by a solution of sodium hydrate, sand was left, a result which I was seeking. This sand was distinctly water-worn, thus showing not the "gentle trituration" quoted by Dana as "evident," but the thunderous dash of waves against rocks whereon the corals flourished; and be it noted that in the South Pacific I have always found the corals thickest on the windward side of the islands, where the surf was heaviest, a result doubtless due to the greater aëration of the water.

In trying to remove some of the larger shells I had the usual experience of beginners in paleontology, and broke my best specimens. In some cases I found that, although the surrounding rock was red and the porous *brachiopod* shell pink, the interior cast was white. I had never heard of the theory that the iron-ore was an original deposit. The "external saturation" theory was supposed to be all-sufficient in those days.

The divergence between the story told by the ore and the explanation usually accepted, became so great that I extended my study of the subject. Dana's account of salt swamps seemed to be a misfit as applied to our local conditions; and such other references as could be gained from scientific papers fell far short of accounting for the presence and conditions of the Clinton red fossil-ore.

I gradually began an attempt to ascertain the geological and paleontological conditions under which the deposit was formed. Deposits are, at best, epitomes of the surrounding conditions. Conversely, if the surrounding conditions are correctly ascertained, there is a probability of some truth in a theory of the consequent deposit. This was my line of reasoning, and I give it at length, because when a worker takes a position opposed to those advocated by geologists of the highest rank, such as I have quoted, he is not entitled to a hearing unless he demonstrates each step of his theory. I believe that the ore was originally limestone and that its replacement has been the necessary consequence of well-recognized geological laws.

There had always appeared to me a weak spot in the "original deposit" idea, which has furnished the following conflicting "evidence:" It was not ŏolithic; it was ŏolithic; it was of organic origin; it was not of organic origin.

No geologist even guessed the source of a quantity so immense that it would sheet several thousand square miles. The question of its condition during transportation, or its place of abode during previous geological time, were not even hinted at.

According to my observation all the above-quoted statements regarding the granules of ore are correct. The same surf that rolled the sand grains into a limestone-forming bottom, washed coral and shell fragments, gravel, limestone, mud and fragments into the deeper water where the corals grew, allowing these substances to subside. Moreover, the quantity of water was so large that mud would not interfere with life, or storms introduce the false bedding that shallow waters show; a condition indicated by the presence of ripple-marks, which do not denote shallowness so much as they do the currents that swept these areas. This mixture of gravel, coral, comminuted shells, dead shells, mud—mostly calcareous in part and derived from the vast areas of Silurian limestones, became the present ore-bed.

The iron came from the decomposition of pyrite, but not by means of thermal waters as Hall has stated. The conditions by which this change has been wrought were and are continuous. There is no hard and fast line in nature; geology and physical geography are inseparable; and a brief statement of the dynamic and structural conditions which caused the coquina-like limestone to be converted into commercial iron-ore is necessary for an understanding of the subject.

III. Resulting Facts and Views.

The results that I have found are as follows:—

The Appalachian Era.

First Stage.—An archipelago, now the Blue Ridge mountains; west of which was an ocean of deposition corresponding to Lower Silurian time.

Second Stage.—A ridge extending SE. from Nova Scotia partly divides the Gulf Stream. The main body flows through

the Mississippi drainage-basin and finds its outlet through Hudson's bay to the Arctic ocean. The eastern or Appalachian sea had its outlet about Chesapeake bay, and was long and narrow.

In the larger or western ocean the fauna was modified from time to time by the reverse, or Arctic, currents that came and went as the land-levels and contours became modified. This condition continued until the close of the Carboniferous age, the northern portion, gradually rising, constricted the northeastern outlet and established lagoons which finally became brackish, as is shown by the fauna they contained.

Third Stage.—The southern part was still under water and Upper Silurian conditions continued, affording a home for the Niagara and Clinton forms of life long after Devonian conditions had been reached in the NE. region. This result is shown by the enormous thickness of the Upper Silurian deposit as compared with the thin black shale which carries *lingula subspatulata* as a characteristic Devonian form. The shales are old mud-banks, and the ocean-bed, now forming Georgia, Alabama and Tennessee, was too far distant from shore to be within the area of the main deposition of mud from the lands of the northeast. The rain must have been excessive, since the moisture-laden air of the Gulf Stream met the frozen winds from the Arctic; and as a result of this heavy rainfall the mud was formed. These conditions continued until Tertiary times.

The Tertiary Period.

Astronomers tell us that many million years ago the precession of the equinoxes caused the earth to be so many million miles further from the sun in its annual course, that at the time of its greatest distance in a period of 10,500 years, the winter was 25 days longer and the summer 25 days shorter than at present. This condition caused the growth of the polar ice-caps, and the earth, following the laws of symmetry which affect all revolving spheroids, suffered surface-changes of level. This condition continued, as shown by the evidence, until the close of the Tertiary period. Nothing was done in a hurry; a gradual local upheaval occurred, during which time the drainages became established through certain channels. A second terrestrial disturbance caused the old axis of upheaval to be-

come dormant, which resulted in a second local upheaval. These successive elevations have been obscured beyond local identification by later denudations and seismic changes.

The Laurentian highlands were a part of the first important result; and later there was a cross-country or E–W. elevation of axis that extended from the Blue Ridge westward in an irregular curve through Virginia into Ohio.

The pre-glacial drainage of the northern area has been the subject of several important monographs and cannot be discussed here. The point of interest is that the drainage thus established cut rapidly down to the base-level and proceeded to erode backward to the drainage-heads, and to broaden the valleys at the lower ends. The "cols" left are marked by low slope-angles. Everything attests the slow and gradual development of the drainages. Since this is the key to the situation of Appalachian development south of the Ohio-North Carolina divide, it is important to note it. Another point suggested is, that after local terrestrial action ceased, it was not resumed at that particular point. In other words, when one fault originates another one near usually becomes dormant.

The Ohio-North Carolina uprise had the very important result of so diverting the Gulf Stream that Hudson's bay was no longer the recipient of the current of warm water that had artificially maintained it in temperate climate. This was succeeded by normal cold water and the channels were rapidly closed by ice. The main body of warm water was split, one part going out by Virginia, Delaware and New Jersey to the north of the uprise, while the southern half, skirting the Blue Ridge about Casars Head, S. C., established an Atlantic flow to the eastward.

Refrigeration continued. The earth's bulk is diminished by cold and increased by heat. It would be easy to calculate an imaginary shrinkage by the loss of a certain quantity of heat-units for a term of several thousand years; but this would not be profitable, since there are no means of proving any part of the calculation. Suffice it to say, that no elevations of surface or crumpling of strata come anywhere near the result indicated by the calculation. There our Appalachian fold originated.

Why the Fold?

All bodies under compression laterally and having one free side, yield towards the free side. In the present case this free side was the bottom of the Appalachian sea. There was less to lift; consequently when the weight of pressure exceeded the weight of the mass of earth the bottom began to rise. The plexus of Balsam mountains in North Carolina was the first resultant—a symmetric group which has suffered longer erosion by drainage than any other. From their base westward a plain of Carboniferous period was slowly rising, as far west as Duck river, Tenn., or even further. Beyond it was the arm of the Gulf Stream still flowing northward.

We now come to a law which may be provisionally adopted, since it explains the geological plications of east Tennessee as nothing else will.

Considering the mountain-mass of the Blue Ridge as the pushing force, and the Rocky mountains as the other jaw of the vise, we find that the action near the pushing force is more intense than further away. This explains why the Smoky mountains and the Balsams are literally piled on end, and why the enormous heat generated by the lifting of such masses caused hot springs in all directions, the action of which is shown by the degradation of the pegmatites to secondary minerals in North Carolina; also the general metamorphosed condition of the Smoky mountain shales, quartzites and limestones, which may throw light on the genesis of the marble and zinc of east Tennessee. With the time-element added, it also explains how the valleys of Virginia and east Tennessee came into being. Drainages westward had to go somewhere, and the folding, incident to positions next to the high fold, caused low folds. Under this law, the high fold had to be east of the low fold; and the erosion of centuries completed the sculpture. Where there is an anticlinal fault, the east side has out-travelled the west side. Under this law the priority of growth of the main anticlinals of the system can be traced. The eastern ones were the first, and they completed their movement before a new one started. That is why the drainage-streams of the Blue Ridge were not turned or diverted. They were lengthened from their heads downward. The elevation of the land was steady but slow, and in no case, on a large scale, was it jerky. The

uprise of the land was equaled by the wear of the beds of the streams.

The same law will explain why the crowded anticlinals of east Tennessee give place to the wide gap of moderate curvature that carries on it Dirtseller, Pigeon, Walden's ridge and other western outliers of the crowded anticlinal areas. After that, pressure is shown by more or less curvature of the bedding of the stratification.

Before leaving this subject, it may be added that, after the earth had passed through this cycle of cold and had commenced to become warm, a stretching of surface took place, as is shown by the evidence. Possibly the floor of the Pacific ocean was lowered gradually about that time and from that cause,—a view which might be supported by some evidence.

For the sake of clearness it may be said that the gradual uprising of the land diverted more and more of the Gulf Stream eastward. The contrary currents, as the ice receded, ran south, reversing the old Paleozoic course and dropping the glacial drifts on the stratified rocks to the southward. These orogenic movements continued until north Georgia and Alabama with east and middle Tennessee had been lifted to the height of the general Carboniferous peneplain, with the highest tilt on the said peneplain on the east side, under the law above stated. Of course, the valley structures were eroding as fast as the level was being raised, but that does not invalidate the law.

It is outside the limits of the present paper to go into the growth of Tertiary and subsequent formations in the Gulf and Mississippi embayment.

With these brief enunciations of geological conditions, I proceed to the particular study of one mountain-mass and the geological and economic results occasioned by the successive changes of its growth.

IV. Lookout Mountain.

Lookout mountain, of which an excellent view from Chattanooga is given in Fig. 1, is unequally divided between Georgia and Alabama, with its narrow and elevated northern termination running a few miles into Tennessee. Geologically, it is part of Sand mountain, Ala., from which it is separated by a couple of anticlinal valleys. It is essentially a synclinal mountain, though

it has, in its northern half, two minor anticlinal axes that have had a marked influence on its topography. Let us view it at the time when, by the operation of the above-named causes, it had got perhaps one-third of its present height. Shinbone valley was buried in the talus of the mountain, and McLemore's, Wills and Lookout valleys did not yet exist. The general scheme was a plain with a slightly upturned edge at the east side tilted by the Shinbone uplift, still slowly going on and not far advanced. The change had been so gradual that the ordinary drainage-conditions had not been disturbed. There was a large surface to drain, and the deep gorges extending to the sandstone resulted. In many cases these gorges, the "gaps" of the country people, are now used for roads. The mountain kept rising. Then the Shinbone anticlinal became dormant and the McLemore's uprise started. Here was a dam gradually rising, and the water found its way northward and eroded McLemore's cove; and southward, the long cañon of Little river.

Little river would have had the same chance of valley-sculpture if it had not been that a large proportion of its drainage was cut off by the next uplift-axis, that of Wills valley, the northern point of which ran under the mountain at Rising Fawn and turned the drainage northward, where it scooped out the cañon-like gorge of Lula falls. It did more than that. It cracked the weaker lower strata and stretched them till drainage formed a series of pot-holes; two or more were in the course of the old river that ran through Sugar Camp hollow to Flintstone. The handsome cataract of that day wore back till the first pot-hole broke through, and a natural bridge was the result. The abutment is still standing on the south side, and is part of the trail leading from Flintstone. Finally, the bridge fell in and formed a dam. The first overflow channel is still visible at the south of the abutment. The dam broke, and the water circling for an outlet washed away Shinbone ridge locally and left the dam piled up on the south of the Gap almost like a terminal moraine of a glacier, made of water-worn Lower Conglomerate sandstone. The present Lula lake is the last of that series of pot-holes and the present drainage-area is insignificant.

The small anticlinal Lookout valley is where the south end of an anticlinal ran into Deerhead cove.

Some accidental and local causes of drainage caused the two valleys to be joined by the gap at Rising Fawn. From the steep side of the western aspect of Lookout mountain, local newness of valley-sculpture consequent upon a deepening of the valley-floor is indicated.

The Iron-Ore.

The above statement is only a recital of the dynamic conditions which led to the formation of the red fossil-ore. Whenever the strains of a bridge or truss are calculated, one portion of the structure has a compressive and crushing strain and another a tensile strain. The same condition applied to Lookout mountain when it was bent into a synclinal trough; the upper part was subjected to a crushing and the lower to a tensile strain. The members under compression are massive sandstone; while the members under tension were and are sandy and calcareous shales, limestones and thin-bedded rocks generally. As a result, the Coal Measures at *A* (Fig. 2) were gradually oxidized and the pyrites became a sulphate of iron solution, which filtered through the sandstones to the axis of the mountain, where, in course of time, it formed a more or less concentrated solution of iron sulphate, and the bowl, *X*, *Y*, *Z*, was constantly fed by the enriched solution. The mountain being axially fractured at its central base as the result of the tensile strain.

The floors of the valleys were too high for bottom-drainage from this acid earth-reservoir. It dissolved the lime from the calcareous shales of the Clinton period. By simple gravity it had already passed through the axial fissures of the mountain limestone and the black shale; the first limestones that were included in the terrestrial reservoir, however, were acted on chemically, and the water became charged with calcium sulphate and was siphoned upward to the accidental level of the springs. Mr. Hayes makes the objection that he has never seen the original limestone unaltered. I have so seen it, but only in one instance. It is indeed rare, and it would be a wonder if it were not. In proportion as the drainage-outlets (springs) of that early day assumed lower levels, due to the deepening of the valley-floors, the limestone outcrops of the higher points escaped impregnation, and, being left high and

FIG. 1.—LOOKOUT MOUNTAIN VIEWED FROM CHATTANOOGA, TENN.

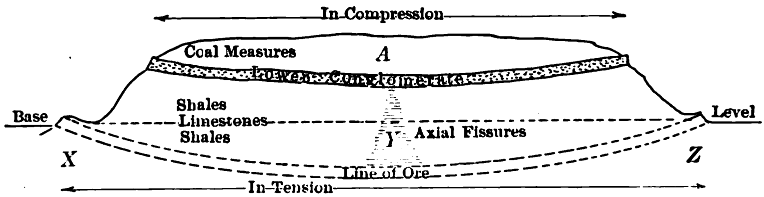

FIG. 2.—SKETCH OF SECTION OF LOOKOUT MOUNTAIN, ILLUSTRATING BOTH COMPRESSION AND TENSION STRAINS.

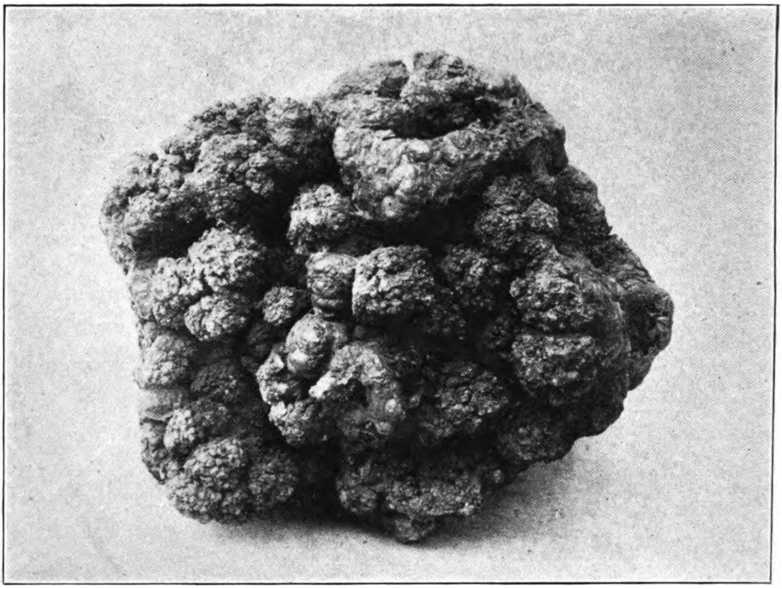

FIG. 3.—"CAULIFLOWER" IRON-ORE.

dry, they were subject to all the causes affecting surface-limestones.

In conclusion, a singular instance of this impregnation *in situ* is afforded by an unusually high limestone which occurs a hundred feet or so below the Lower Conglomerate. On the road from Valley Head to Mentone, I saw about 2 ft. of a fossil limestone, the upper part of which had been converted into a regular iron-ore. It had a water-tight shale below it, repeating on a small scale the action of the larger influence of the Tertiary and Mesozoic periods. Furthermore, it contained pieces of coal about the size of wheat, and occasionally the size of a coffee-bean. With regard to the character of this coal, it had the clean cubic and conchoidal fractures of coal, and was neither sea-wood nor wood; undoubtedly the pieces were deposited in the ocean, but I do not know from whence they came; probably the ice brought them from some other region, since this time was before the lowest coal of the district came in. As an additional puzzle, I may say that at Inman, Tenn., ore-mining a lenticular mass of coal, 10 or 12 ft. long, 2 ft. wide, and several inches thick, embedded in the Clinton ore. I have specimens showing the ore and coal together. Probably the ice must be responsible for this effect. Favoring conditions, rather than the date of genesis, have determined the growth of such formations.

Mechanical Texture of the Ore.—If my views are correct, it follows that every particle of the iron has been deposited from solution. If that be granted, then the laws of segregation of like substances from solution must have been followed.

A bunch of "cauliflower" iron-ore having the peculiar "cauliflower" structure is shown in Fig. 3. This specimen was originally a lime stalactite, but recomposition *in situ* has substituted iron for lime.

There was another complex action at work. The enormous quantity of carbon that was to be locked up in the coal-beds of the coming Carboniferous era was largely in the form of free carbonic acid, which conferred upon the rain an intense solvent power for the Silurian limestones and the harder and older rocks that were above drainage-level. This condition made the sea-water rich in lime, which is shown in the enormous profusion of corals, brachiopods and mollusks. When these shells

were no longer tenanted, they were thrown by sea-action on the beach; superficial solution eroded their surfaces, Eolian sand-action ground them, waves fractured them till those that escaped actual trituration and re-solution were washed into the deeper water, the resultant carbonated water-action being corrected by the plant-life which, in turn, acted on the dissolved gas. Infinitesimally small differences in permeability caused local *nuclei* of iron deposition in the texture of the rock, which occurred after the shell-mass had been converted by time and pressure into rock. The following evidence proves the existence of such local pressure. I have a specimen of *platyostoma* that originally rested on its side but now has its two sides pressed almost together. The breadth of the hinge-line has become the thickness of the shell.

While infiltration of waters charged with iron sulphate was slowly converting the iron into ore, the action of carbonic acid gas in the same rains, together with the humic and ulmic acids derived from surface vegetation, had rendered soluble a portion of silica which was concurrently introduced and became a constituent of the ore, being, I suspect, the source of the silica which Diller, in the passage above quoted, describes as "radially fibrous and optically negative, like chalcedony."

A confirmation of this conclusion was observed at Battelle, Ala. The ore there occurs in the Lookout valley on the west, a black shale ridge supposed to be Devonian, having the siliceous bottom of the Carboniferous on its eastern haunch. The ore dips to the east, being the western margin of a synclinal trough. The Alabama Great Southern railway runs to the east of this ridge. The hard ore of the deposit contains, on an average, about 28 per cent. of iron and 9 per cent. of silica. To ascertain whether the ore-deposit was of any extent or could be reached by shaft, a drill-hole was sunk in the East valley Carboniferous fully half a mile east of the outcrop, which showed a 4-ft. deposit of ore at 800-ft. depth, having the following composition: Fe_2O_3, 73.23; CaO, 14.33; SiO_2, 4.52; and P_2O_5, 0.35 per cent.

No surface influence could have made any impression at this depth, which exceeded 750 ft. below the drainage-base level. It was alike free from lime-leaching and siliceous infiltration. This fact is a broad indication that the deposit was formed

under such conditions as exists in this particular field, and it would seem to indicate the probable impregnation from axial influences. Mr. Henry McCalley, in several conversations on this subject, was inclined to take the view that the original iron-ore was deposited as such, saying that he has seen a syncline in which the deep drilling passed through strata of the proper horizon where ore showed at the edges and found no ore in the drill-hole. This effect might indicate that the bottom of the fold lay too deep to be affected by the basin of enriched water, whose downward limit is, as has been said, soon confined by the mud resulting from the insoluble material in the limestones that are dissolved, the mud washing off the exposed faces as each particle became loose. Much of the granular appearance of the ore may be iron which coats the small partly-solution-rounded shell or coral particles in its characteristic pisiform mode of segregation. When a broken shell is partly dissolved, the tendency would be toward flattened or elongated grains, since solution in *brachiopoda* remains would be greater on the grain than across it. With *protozoa*, the organic structure may be more or less obvious or wholly obscured according to the degeneration of structure consequent on mineralogical replacement.[4]

V. Conclusions.

These material features and facts concerning Lookout mountain might be dismissed as local, were there not certain underlying facts that are keys to the conditions attending the conversion of limestone into ore. These facts are:

1. The presence of synclinal plateaus, now often reduced to peneplains, the troughing having been occasioned by crushing.

2. Streams that have cut their way to the base-level, effecting a lodgment and establishing a bed on the Trenton limestones.

3. Mountain slopes of softer materials and easy of wear, that were capped by heavy sandstones. These slopes, undermined, broke off, and formed a more or less protecting coating to the talus of the mountains.

4. The continual overflow from the underground basin de-

[4] Since writing the above, Mr. McCalley has kindly shown me his microscopic sections of the ore. In every case either the center was lime or animal structure was evident.

scribed above formed innumerable springs, which, by their discharge, modified the valley-sculpture.

5. The conditions of orogenic activity were transferred from the eastern American Continent to other parts of the world.

6. At the outcrops, familiar influences have removed a part of the lime still remaining in the ore and have introduced silica, etc.

7. The process is still active. Occasionally a little of the ferrous water escapes unchanged; we call it a "sulphur" spring. Where the normal conditions exist, the water that fell as rain has been rendered hard by calcium sulphate, the iron from the top of the mountains replacing the lime *in situ.*

I have never met a case at variance with the principles announced above, any conflict being easily traceable to local causes.

One other consideration is involved. When the axial channels were made by stretching the base of the anticlinal mountains, the influence would be deep; but at the first action of substitution of iron for lime, the clays and other materials of the limestones, together with the dirt, would be deposited and choke up the channels below a level lower than that of the existing drainage, thereby protecting the deeper strata from impregnation, and localizing the area to the one porous coquina-like limestone.

The whole subject needs study, and I ask the co-operation of those who, by location and occupation, have daily access to the ore, in noting such facts as would seem to bear on the subject either for or against the views I offer. Then, with broader light, we may make substantial progress.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Anthracite-Washeries.

BY GEORGE W. HARRIS, NEW YORK CITY.

(British Columbia Meeting, July, 1905.)

Introductory Summary.

In the earlier period of anthracite-mining, much coal was wasted, both underground and in the culm-banks on the surface. Such waste is common in the development of new mining districts, in which, as a rule, only the richest material can be profitably treated. In the anthracite-region, special causes operated to increase this evil. The mines were generally operated under 20-year leases, and royalties were paid upon such coal only as was actually marketed. The lessees consequently cared for immediate profit only. They were not bound to win all the coal they exposed, or to leave it in such condition that their successors could win it. Nor was it their interest or duty to educate consumers in the use of their product. The market called for coal of large sizes; and such coal they furnished, throwing away the rest. Any pains taken by them to bring about a more rational use of coal by their consumers would have borne fruit, after their leases had expired, to the benefit of somebody else.

A full statement of the situation was given in 1893, in the report of the State Commission, appointed in 1889 to investigate the subject.[1] That body included the names of Heber S. Thompson, William Griffith and the late Eckley B. Coxe.[2] Its report gives special attention to the utilization of the old culm-banks.

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[1] Report of Commission Appointed to Investigate the Waste of Coal-Mining, with the View to the Utilizing of the Waste, May, 1893.

[2] For a statement of Mr. Coxe's great services in this respect, see Dr. Raymond's Biographical Notice of him, *Trans.*, xxv., 448; also, for further information, *Trans.*, i., 9, 55, 59, 406; iii., 13; v., 417, 465; ix., 294; xi., 7; and sundry volumes of the Penn. Geol. Survey, especially A_2 (1881), on "The Causes, Kinds and Amount of Wash in Mining Anthracite."

Meanwhile, this colossal waste, both below and above the surface, of a valuable and limited national treasure, had received its first check through the concentration of the control of the anthracite-mines in the hands of a few wealthy firms and corporations, which had both the motive and the means for measures of economy looking to a more distant future, and were guided by intelligent men, who knew the value of scientific advice.

The consequent improvement of mining methods, by which the unnecessary waste of coal underground was stopped, is outside the limits of this paper, which is concerned with the waste in the breaker, represented by the old culm-banks.[3] The first step towards the diminution of this waste was the commercial introduction of smaller sizes of coal. This required the education of consumers to the use of such sizes. "Pea," "Buckwheat," "Buckwheat, No. 2" ("Rice") and "Buckwheat, No. 3" ("Barley") successively achieved recognition as articles of trade. The rapid increase in the production of the sizes below chestnut is shown in Table I., taken from a report by H. H. Stoek.[4]

TABLE I.—*The Product of Small Sizes of Anthracite from* 1875 *to* 1903.

Sizes.	1875.	1880.	85.	1890.	1895.	1900.	1903.
All sizes..............	20,000,000	23,500,000	32,000,000	37,000,000	46,500,000	51,500,000	59,362,831
Lump, steamer, and broken......	7,500,000	9,000,000	7,500,000	9,000,000	8,000,000	7,500,000	7,179,720
Egg & chestnut..	11,000,000	11,500,000	18,500,000	19,000,000	24,500,000	26,000,000	(a)31,112,120
Chestnut and larger..............	18,500,000	21,000,000	26,500,000	28,500,000	32,500,000	33,000,000	....
Pea.....................	1,000,000	2,000,000	3,500,000	4,500,000	6,500,000	7,500,000	8,576,340
Pea and smaller.	2,000,000	3,000,000	6,000,000	8,500,000	14,000,000	18,000,000	....
Buckwheat and smaller......	150,000	500,000	2,000,000	3,500,000	8,000,000	11,000,000	(b)12,494,651

(*a*) Including stove-size. (*b*) Buckwheat Nos. 1, 2 and 3.

[3] I speak of the *old* culm-banks, because the recent accumulations of that class, though they look to the inexperienced eye as carboniferous and promising as their predecessors, are by no means equally valuable. Many of them represent essentially only black slate, not yet (and perhaps never) to be utilized for its very small content of combustible carbon. One of the largest old banks is at the Von Storch colliery of the Delaware and Hudson Co., within the limits of the city of Scranton.

[4] "The Pennsylvania Anthracite Coal-Field," 22*d Annual Report, U. S. Geol. Survey*, 1902, Part III., p. 55.

The reports of the collieries of the Girard Estate show that small sizes of coal were thrown upon the dump prior to 1866, at which time chestnut was the smallest size sent to the market. In 1867, pea-coal was utilized for fuel; in 1878, "buckwheat" was shipped; in 1895, "rice;" and quite recently "barley," No. 3 "buckwheat." No record of shipments of culm or coal-dust from the Girard Estate collieries was made prior to 1902.

A fair estimate of the quantity of coal and coal-dirt sent to the culm-banks from the commencement of mining operations up to 1903 is about 315,700,000 tons, or 35 per cent. of the total production during that period.

The different conditions of mining in the anthracite-regions have affected largely the character of the resultant culm-banks. In the middle and upper portions of the Lackawanna region, from near Wilkes-Barre to Forest City, the seams have little pitch, and most of the loose rock resulting from mining operations was left in the chambers; while in the steeper seams of the middle and southern regions, practically the entire product of the mine was frequently loaded in cars and sent to the surface, the rock and much of the coal-screenings being placed in the same dump. Moreover, the dry preparation of coal in the Lackawanna region tended to a greater saving of the smaller sizes, which were stocked in banks. On the other hand, wet preparation in other regions was more wasteful of the fine sizes, much of the mined coal being carried away and lost in the water used in washing. In other instances, the culm was spread over many acres of ground, destroying vegetation and generally contributing to the barrenness of tracts already denuded of timber. Under these conditions the recovery of the smaller sizes of coal became difficult, if not commercially impracticable. These circumstances indicate the Lackawanna region as the natural field for washery operations; and it is in the Lackawanna and Wyoming valleys that the greatest development of this branch of the coal-industry is found.

During the year 1903, the shipments of coal from washeries [5] amounted to 3,677,909 tons, of which quantity, 2,875,981 tons (about 78 per cent.) came from the Lackawanna region, and

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[5] *Report of the Department of Mines of Pennsylvania*, 1903.

309,244 tons from the Pottsville districts. This output from the washeries constituted 5.92 per cent. of the total quantity of coal sent to market in 1903.

Typical Modern Plants.

General Description.

In view of the above statistics, a description of one or two typical modern plants is appropriate.

In general, the machinery and some of the methods used in washeries do not differ materially from those seen in portions of breakers preparing the smaller sizes of freshly-mined coal; in fact, the washery is often an annex to an old breaker in which the coal is prepared dry. The important difference is that the washery is essentially "wet:" the success of this practice being largely due to the abundant use of water, which not only removes clay and coal-dirt, but greatly assists in the separation of the various sizes on the screens. It may be said that the washery, while it has features peculiar to itself, is but a development of the breaker to meet special requirements.

Starting at the culm-bank, the first step in the operation is the transportation of the material to the washery. The culm is fed to conveyors by hand or by steam-shovel; then loaded into cars, which are hoisted to the top of the washery; or, as is becoming common practice, it is flushed into conveyors by means of a hose, as in hydraulic mining—a stream of 2.5-in. diameter being sufficient to carry the culm to the conveyors in sheet-steel chutes placed at a slight angle to the horizontal (see Fig. 1). As the bank recedes, the chutes are taken up, the underlying culm is shoveled into the conveyor, and the scraper-line is moved closer to the bank. Generally, there are several lines of conveyors, the one nearest the washery being permanent, and the others (feeding into it) movable. A difficulty often encountered in working these banks is the occurrence of ashes, from the boilers of former times, which have been mixed with the coal on the bank. The separation of these ashes from the valuable portion of the dump is often an expensive operation.

This general practice of flushing into conveyors is followed at the Capouse washery of the Scranton Coal Co. in the Keyser

FIG. 1.—FLUSHING CULM INTO THE TROUGHS WHICH FEED THE CONVEYORS.

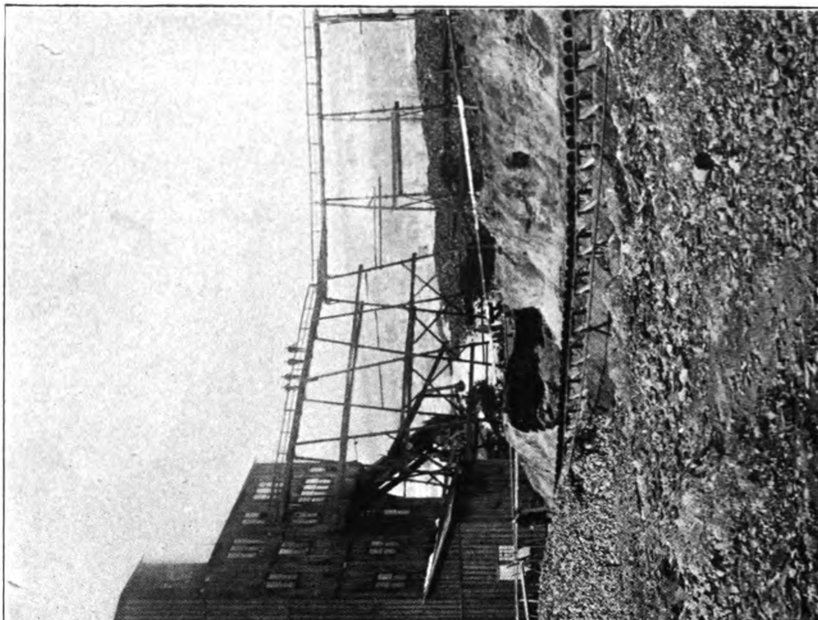

Fig. 2.—Capouse Washery near Scranton, Pa.

valley, north of Scranton, on the New York, Ontario and Western railroad. This company also operates the Mount Pleasant washery at Scranton, and the Raymond washery at Archibald.

The Capouse Washery.

At this plant there is a fixed scraper-line, 380 ft. long and a 500-ft. movable conveyor, each driven by an independent 10- by 16-in. Nagle engine. These endless-chain conveyors run in a framework, the bottom line moving in a sheet-steel or cast-iron trough and returning on T-rails overhead.

The conveyor delivers the fine material at the foot of the main elevator of the washery, where it is washed, sized, the slate removed and the large pieces of coal re-broken. A typical plant for handling culm containing few pieces of large size is illustrated in Fig. 2. These conditions are similar to those at the Bellevue washery, which I have elsewhere described.[4]

The washery, having a capacity of 120 tons of prepared coal per hour, occupies an area of about 53 by 65 ft. at the foundations, and is approximately 80 ft. high. Figs. 3, 4 and 5 show the details. The frame of the building is of morticed construction with 12 by 12-in. posts braced by 8 by 8-in. timber. The stringers supporting the machinery and those under the coal-pockets are of 12 by 14-in. oak. The compactness of this plant is quite striking when compared with coal-breakers having a similar capacity. In marked contrast also is the absence of the clouds of coal-dust which arise during working hours at the breakers in the Lackawanna region.

The preparation of the coal at the Capouse washery begins at a point where the scraper-line discharges into a chute leading to the main elevator. A man stationed here throws out large lumps, breaks those containing coal into smaller pieces, which are then thrown into the elevator-boot, *A* (see Fig. 5), removes any pieces of foreign material—wood, iron, slate, etc., and controls the feed of the coal to the elevator. In the washery, the main elevator is 65 ft. long from center to center of sprocket-wheels, and carries 71 water-tight buckets, each 12 by 28 in. in size. The elevator material is discharged into a chute, *B*, which feeds the first shaking-screen, *C*. (In washeries

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[4] *Mines and Minerals*, Scranton, Pa., June, 1903, p. —.

the revolving, circular screen has been almost entirely superseded by those of the flat shaking type because the fine mesh

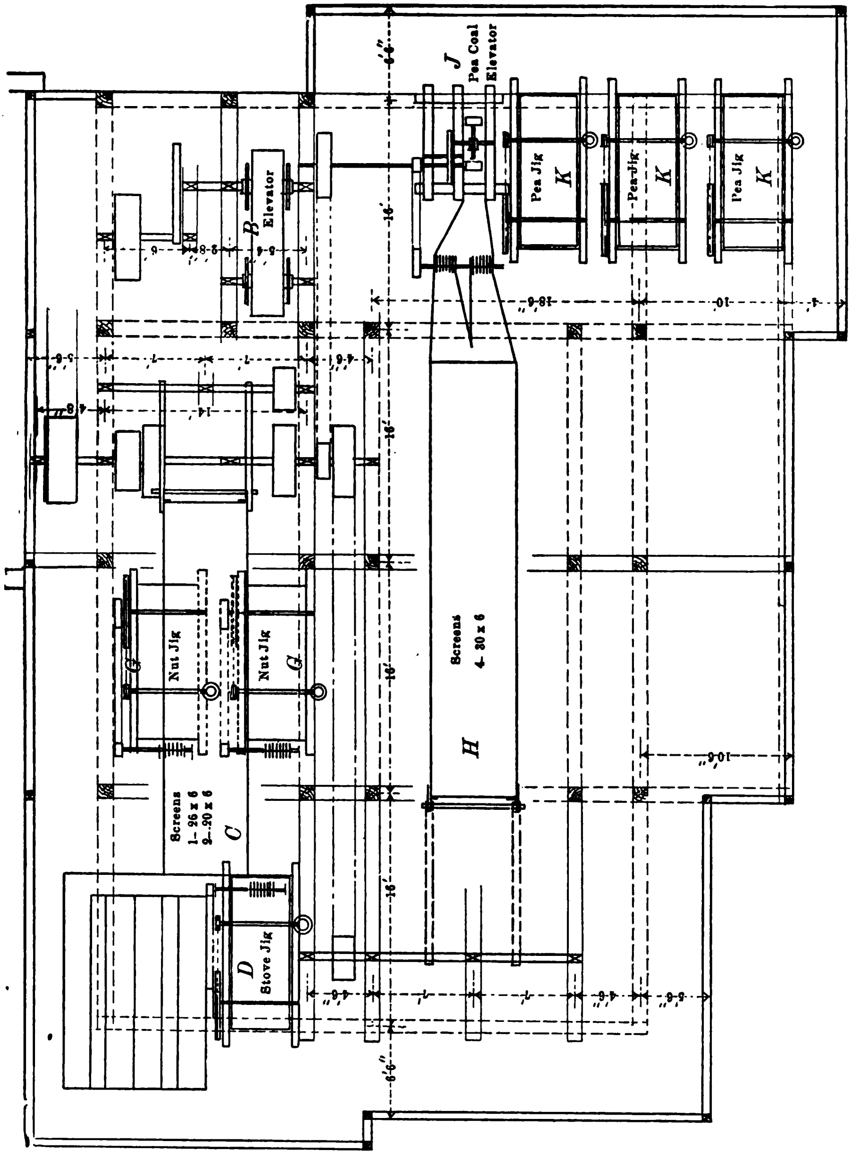

FIG. 3.—CAPOUSE WASHERY—PLAN, SHOWING THE POSITION OF THE MACHINERY.

of the former becomes clogged with dirt, despite all efforts to prevent it.)

The shaker or "mud" screen, *C*, consists of three screens, the top one being 27 by 6 ft. and the two others 20 by 6 ft. in

area. The screens are driven by eccentrics, set so that each one receives a thrust at a different time from the others, an arrangement which is necessary in order to avoid undue vibration of the framing. As soon as the material strikes the top screen, it is sprayed with water from a perforated pipe; and, passing down the screen, goes under a box from which a copious stream of water overflows. The first 21 ft. of the top screen have

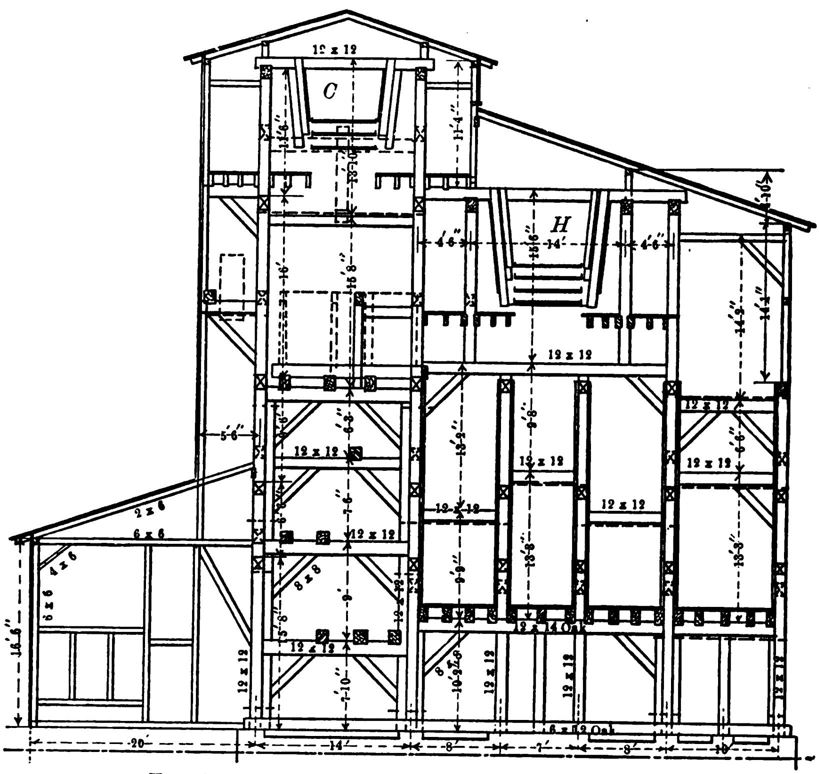

Fig. 4.—Capouse Washery; Transverse Section.

1.5-in. round holes, through which pass chestnut and smaller size pieces to the screen below. Next to the 1.5-in. round holes are placed angle-iron, having the angle uppermost, thus—Λ, the edges spaced 0.75 in. apart, which allows flat pieces of slate to fall through. The last 4 ft. of the top screen have 2-in. round holes which permit pieces the size of stove-coal to fall through to a chute; pieces larger than 2 in. pass over the end of the screen to another chute. The stove-coal goes to jigs, *D*,

thence to rolls, *E* and *F;* and, after being broken to pea size and smaller, to the main elevator-boot, *A*.

The large coal is hand-picked by six men and boys and the slate removed, after which it is sent to the rolls and the main elevators. The coal that drops through the top screen of the shaker, *C*, falls on to the second screen having $\frac{7}{8}$-in. holes, the chestnut-size passing over, and pea and smaller sizes dropping

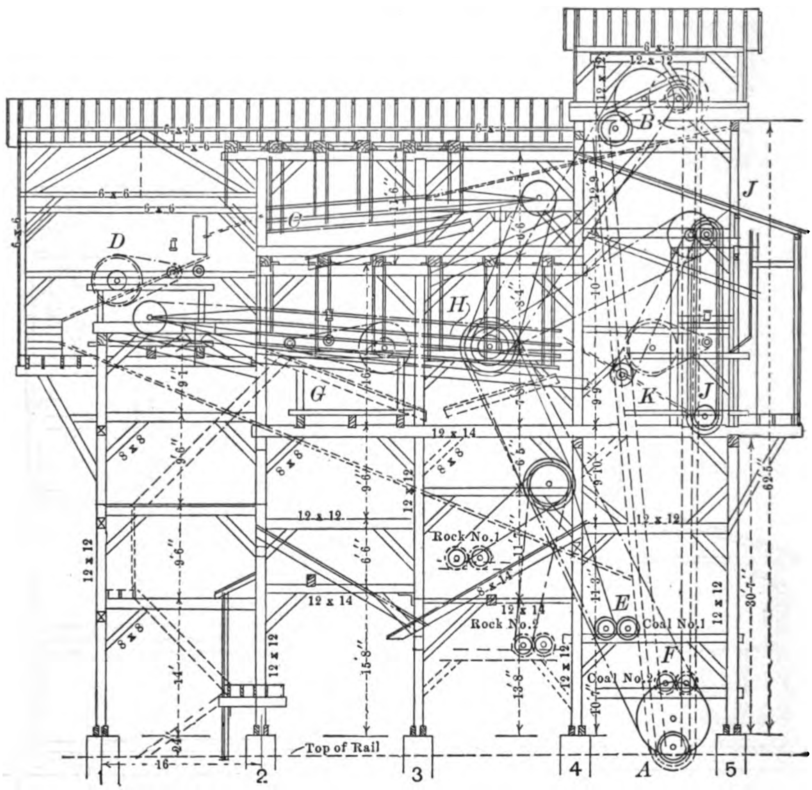

Fig. 5.—Capouse Washery (Partly in Elevation). Longitudinal Section.

through to the lowest screen. The chestnut-size goes to jigs, *G*, thence to rolls, *E* and *F*. The bottom screen has $\frac{3}{32}$-in. holes which permit the fine coal-dirt, slush or culm (it is called by all three names) and mud to pass through to a trough which delivers to a settling-pond near the washery where the stream spreads over a large, nearly level, area and deposits the suspended materials. The pea-size and smaller sizes of coal pass over the bottom screen to a second shaker, *H*.

The shaking-screen is simple in construction, effective in action, occupies little space and needs few repairs. At the Capouse washery, each screen is suspended by $\frac{7}{8}$ by 8-in. ash boards, their upper ends bolted to overhead beams and the lower to castings which journal on bars passing under and supporting the screens. Two boards, comprising the hanger on each side, are set at an angle from the vertical so that they act as braces and prevent the screens from swaying sideways. When suspended by rods, the screen travels between guides to insure greater steadiness. Both methods of suspension are used, the boards having the preference.

The shaker, *H*, consists of four tiers of screens, the top one having an area of 30 by 6 ft., the next lower 26 by 6 ft., and the two lower being 20 ft. long by 6 ft. wide. The coal passing through this shaker is separated into sizes as follows:—the top screen with 0.5-in. mesh allows the pea-coal to pass over, and No. 1 buckwheat and all smaller to drop through; the next screen, with 0.375-in. mesh, separates No. 1 buckwheat from the smaller sizes, the latter dropping through to the next lower screen with a $\frac{1}{4}$-in. mesh; this last screen makes No. 2 buckwheat or rice-coal; No. 3 buckwheat or barley passes over the lowest screen which has $\frac{3}{32}$-in. mesh, through which drops the fine coal to be carried by the wash water to settling pond No. 2. The wisdom of keeping the mud from the shaker, *C*, separate from the fine coal of the shaker, *H*, when possible, will be more apparent as time goes on, and this fuel becomes valuable as material for briquettes or for burning as dust.

The 3 buckwheat sizes from the shaker, *H*, go direct to pockets, but the pea-coal must be cleaned of slate. After the pea-size leaves the top screen it passes down a chute, in which is a triangular device raised about 0.5 in. above the bottom, so as to allow flat pieces of slate to pass under while the coal goes to the elevator, *J*, and so to the jigs, *K*. After leaving the jigs, the coal passes through a Pardee spiral picker for further cleaning and thence to a pocket.

A number of features about this washery are deserving of special mention. The six jigs (of the Christ type and measuring 11 ft. by 5 ft. 4 in. by 6 ft. 9 in.) are driven by a 7 by 8 in. engine. The coal receives a reciprocating motion in a pan immersed in water, which action causes the slate to sink, while

the lighter coal passes out at the top. Generally three jigs are sufficient to clean the coal, the others being held in reserve. The larger-mesh screens on the shakers are of steel; but those of $\frac{3}{32}$-in. mesh, on account of the small perforation, must necessarily have thin metal to prevent clogging, and therefore are made of bronze, in order better to withstand the action of the acid mine-water used in washing the coal. At the Capouse washery, the shaker, *H*, has, above the tier of screens, four overflow water-boxes, which are very efficient.[6]

The shaker, *C*, receives from 165 to 170 thrusts per minute and the shaker, *H*, about 180. To re-break large coal to pea-size and smaller, two rolls are used, the roll, *E*, being 24 by 24 in., and *F*, 21 by 24 in. The two rock-rolls shown in Fig. 5 were used to crush slate, taken from the coal, to a size not larger than pea, which was then sent with the fine coal to fill old mine-workings, a method since abandoned at the Capouse washery.

As previously noted, a large quantity of water is most important for successful washing, and the supply for the Capouse washery is obtained from an adjacent shaft. A bull-pump raises water from the mines and delivers it to a reservoir near the washery, the pumping-equipment of which consists of 3 No. 10 Knowles pumps, 16 by 10 by 16-in. It is estimated that each pump furnishes 500 gal. per min.; two pumps raise water to the top of the washery, through their two 6-in. columns which connect at the top; the third pump supplies water for flushing the material into conveyors at the culm-bank. All water-pipes about the plant are at such an angle that when work stops, valves are opened and the water drains out, thus preventing the pipes from freezing up in cold weather.

The machinery is operated by a 24 by 24-in. Dickson engine, running at 78 rev. per minute. The steam is supplied by

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[6] A similar shaker at the Bellevue washery is equipped with a different device. A pipe carries the water close to the coal on the top screen ; and a piece of sheet-iron fastened to the pipe directs the water in a flat spray against the direction of the moving coal. This retards the coal and turns it over, thus facilitating the sizing and cleaning. Four sprays, equally distributed along the length of the shaker, are used for this purpose. The shakers have a pitch of 1 in 12 in the direction of the flow of coal, and receive a thrust or reciprocating movement of 5 in. from the eccentrics connected at the upper end.

three fire-tube boilers, housed in a substantial brick building, situated at a distance of 500 ft. or more from the washery. The labor required to run the plant consists of from 40 to 50 men and boys, a larger number being needed in winter than in summer, to clean out railroad-cars, etc. The outside force includes a foreman in charge of the whole plant; 2 hose-men; 10 or 12 men on conveyor-lines; 2 men to run the conveyor-engines; 1 man at the elevator-boot; and 2 men at the settling-ponds. The force inside the washery is distributed as follows: one machinist or oiler; 1 carpenter or repair-man; 3 jig-runners; 8 slate-pickers; 1 engineer; 1 man at the head of the main elevator; 4 loaders; 2 car-repair men; 6 slate dump men. In addition, there are at the boiler-house 3 firemen; 1 man to cart out ashes, and one man to wheel in coal. The Capouse plant has shipped coal since November 1, 1900, and during 1904 worked 182⅓ days of 9 hours each, producing 184,004.7 tons. The record for the washery was made in January, 1902, when 31,018 tons were produced in 262½ hours.

Other Plants and Practice.

The Nottingham Washery.—In the Capouse plant, which makes pea and buckwheat, the machinery for removing slate consists of 6 Christ jigs and 1 spiral picker, through which the large coal is cleaned before going to the rolls. A different method is followed at the Nottingham washery of the North American Coal Co., of Plymouth, a plant making 6 sizes of coal, from stove to No. 3 buckwheat (*i.e.*, barley). At the latter plant 11 Pardee spirals and 1 Emery picker are employed to remove the slate mechanically. There are also other important differences. The Nottingham washery contains 3 shakers and 3 pairs of coal-rolls. The large coal from the first shaker or mud-screen, after being hand-picked, is sent direct to the rolls, and finally cleaned of slate in the spirals just before going to pockets. The first or mud-screen sends pea-coal to pocket, the second shaker makes three sizes of buckwheat and the third shaker produces stove-, nut- and pea-coal. This plant employs on an average 58 men and 18 boys, and has a capacity of 100 tons an hour. The Nottingham culm-bank contains a considerable amount of large coal, which is not re-crushed as fine as at other plants.

The Schuylkill Washery.—This plant of the same company embodies features peculiar to the handling of culm-banks containing larger pieces of coal (or coal and slate) than either of those above noted. At the Schuylkill works, men with sledges break up the largest pieces at the bank before the material is flushed into conveyors. Before passing into the washery proper, the coal goes to a shaking-screen with two decks, the upper of which has 5.5-in. and the lower 2.75-in. mesh. Everything dropping through this shaker passes direct to the main elevator. The two grades of large coal passing over the screens go to separate chutes, where men pick out the slate, after which the coal goes to rolls, is broken to egg-size and smaller, and then passes to the main elevator.

The Delaware, Lackawanna and Western Washeries.—An interesting feature of these washeries is the mechanical method used for ascertaining the percentage of slate in every car of coal shipped. As a car is being loaded, samples of coal aggregating 10 lb. are taken at different intervals and thoroughly mixed; and 3 lb. taken therefrom are placed in a perforated copper pail. The pail is then suspended in an earthenware jar containing sulphuric acid, of a specific gravity half-way between those of coal and slate. As a result, the coal floats on top and is skimmed off, while the rock and slate, sinking to the bottom of the pail, are withdrawn from the liquid and weighed. The weight of the impurities, compared with the weight of the 3-lb. sample taken, gives the percentage of slate in the coal.

Local Variations in Practice.—In some instances, particularly in the Schuylkill region, the culm-bank is loaded by a steam-shovel into mine-cars, which are hoisted up a plane to the top of the washery and then dumped. Here the material may pass over bars and the large pieces may be handled on a platform, as in breakers.

In many washeries the "bony," or pieces of mixed coal and slate, constituting the "middlings" between clean coal and clean slate, are re-broken and sent over the screens a second time, thereby recovering a considerable quantity of good fuel.

General Remarks.

It is interesting to note that of the 13 coal-producing operations of the Girard Estate during 1903, 2 are classed as wash-

eries; yet of the 11 collieries, the production of 2 came in 1903 almost entirely from culm-banks, and 6 others very materially augmented their output from this source. Thus the 2 washeries shipped 230,039.18 tons or a little more than 15 per cent., while coal reclaimed from culm-banks formed 30.7

TABLE II.—*Shipments of Coal from Washeries During* 1903.

Name of Company or Washery.	Size of Coal.								Total.
	Egg.	Stove.	Nut.	Pea.	Buck-wheat.	Rice.	Barley.	Culm.	
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Scranton Coal Co. (1904):									
Capouse Washery	....	....	....	9,483.12 (5.15%)	57,785.15 (31.41%)	41,112.13 (22.34%)	75,622.07 (41.10%)	....	184,002.47
Mt. Pleasant Washery	....	....	....	13,725.13 (6.93%)	41,851.18 (21.11%)	51,320.17 (25.89%)	91,321.07 (46.07%)	....	198,217.55
Raymond Washery	....	....	....	14,755.16 (7.48%)	54,546.16 (27.64%)	52,227.01 (26.46%)	75,816.18 (38.42%)	....	197,344.51
North American Coal Co. (1903):									
Schuylkill, No. 1	....	8,400.90 (4.83%)	17,082.55 (9.81%)	25,472.85 (14.63%)	63,321.85 (36.38%)	48,514.65 (27.87%)	11,164.55 (6.42%)	129.70 (0.06%)	174,087.05
Raven Run Coal Co. (1903)	....	....	5,390.70 (9.64%)	10,084,20 (18.02%)	22,157.70 (39.60%)	18,320,25 (32.74%)	....	....	55,952.85
Girard Colliery (1903)	169.75 (0.33%)	1,403.85 (2.71%)	4,691.30 (9.06%)	16,725 30 (32,32%)	16,951.75 (32 76%)	11,808.85 (22.82%)	....	....	51,750.80
D., L. & W. R.R. Coal Dept. (1904)	....	....	....	....	196,250.00 (25%)	274,750.00 (35%)	314,000.00 (40%)	....	785,000.00
Total	....	....	....	....	....	....	....	....	1,646,355.23

per cent. of the total shipment of 1,515,213.14 tons, from all the operations of the Estate.

The proportions of the various sizes of coal found in culm-banks varies in the different banks and also at times in the same bank. Table II. shows the shipments in 1903 from a

number of washeries throughout the anthracite-field, and gives a fair idea of what is generally reclaimed. While this table gives the coal produced from banks, it does not generally indicate the sizes going to the washery; for in most cases the larger pieces are re-broken. For example, the Delaware, Lackawanna and Western Coal-Department makes nothing larger than buckwheat-size at the washeries, everything in the banks being broken to that size and smaller.

Washery-coal appeals to the operator and the engineer, as well as to the consumer of fine coal, particularly in cities. The operator sees in these large accumulations from former mining operations a great quantity of coal readily available for quick shipment when occasion demands. During the anthracite strike of 1902, these washeries, being comparatively easy to operate, and requiring a relatively small number of men (mainly unskilled), were for months the only productive source of hard coal. Large shipments from these plants were made for some time after the mines resumed; and for this cheap supply of smokeless fuel there was a great demand from steam-users in many neighboring cities. From an engineering standpoint, the reclaiming of coal from culm-banks is gratifying, because it recovers value from the great waste which attended the early mining of anthracite.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Notes on Southern Nevada and Inyo County, California.

BY H. H. TAFT, DENVER, COLO.

It has long been known that the volcanic area south of Belmont, Nye county, Nevada, had mining possibilities. Some of the old-time prospectors knew that gold existed there. Its remoteness from any source of supplies, its long distances from water, the absence of game, and more, perhaps, the lack of grass for animals to subsist upon, has made this an unattractive region in which to search for mines.

The decline of the Comstock mines, the exhaustion of sundry large and rich ore-bodies, the high cost of mining, marketing, and particularly the ruinously high freight-charges upon refractory ore that had to be shipped to distant smelters, have kept investors out of Nevada for the last few years; and mining people have hardly yet awakened to the importance of Tonopah, Goldfield and perhaps the newer and less developed districts.

The discovery of Tonopah by J. L. Butler, who located the Mizpah Claim in May, 1900, and the fortunes soon realized there, attracted many people. As the boom declined, many went away, some scattering out into the surrounding country, and the population is now about 7,000. In the fall of 1902 a discovery of gold was made 23 miles south, in what is now known as the Sandstorm group, 4 miles NW. of Goldfield. In the winter of 1903–4 the Combination, January and Florence mines were discovered, and shipments of high-grade ore soon followed.

In January, 1905, there were 10,000 people in Goldfield. In June, 1904, rich gold-ore was found 85 miles SE., at the foot of the south end of the Kawich mountains, but this discovery was kept quiet until a re-location could be made.

On August 10, 1904, the Bullfrog claims, and a month later the Ladd mountain and neighboring claims, were located. The Shoshone group was located September 24. This district is

from 60 to 80 miles SE. of Goldfield. In September, 1904, there was a stampede for Bullfrog and Gold Crater—the latter a small area 21 miles east of Goldfield. Two mining districts, called Beatty and Bullfrog, were organized under the laws of Nevada. Later, overflow migrations poured into the old and abandoned districts of Lida (or Allida), Tule Cañon, State Line and Silver Peak, and others more remote.

During the winter of 1904–5 the desert seemed full of people. All sorts of outfits traversed unfrequented roads—men afoot and alone, "burro men," carriages, wagons and automobiles. The inevitable reaction of such furore is no doubt deplorable; yet the rapid development of any new mining region depends upon the excited "tenderfoot" rather than the conservative mine-operator. At Goldfield, it was "a sight to see." There were hundreds of people walking over the hills, many with a canteen of water slung over one shoulder, while a small iron mortar hung to the other, and a pestle, a pick and a 5-in. frying-pan constituted the equipment for sampling, grinding and testing. The rock is soft and the gold at the surface is free.

There is no very good map of this region. The best is that of the U. S. Geological Survey[1]; but this and the Land-Office maps are incorrect, particularly in the topography between the northwest arm of Death valley ("Lost valley") and Owens Lake. A correct map of Inyo county, Cal., has been made by the County Surveyor. A very useful map, particularly of the country farther south, is issued by Mr. Crowell, of Vegas, Nev.

The high Panamint range is usually mapped with about twice its actual length. It ends at latitude 36°30′ north. A wagon-road from Furnace creek in Death valley to Ballarat in the Panamint valley follows around this mountain at its base. The geological maps would be far more useful to prospectors if the older tertiary volcanics were separated from the recent ones. A good map showing the potable waters would save much suffering, and perhaps some lives, this summer. The springs should be marked by the Government. So far this year about 30 lives have been lost on account of thirst in that desert region.

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[1] Bulletin No. 208, *U. S. Geological Survey.*

Tonopah is 6,000, Goldfield 5,500, and the Bullfrog region from 3,500 to 4,000 ft., above sea-level. The climate at Goldfield is much the same as that at Pueblo, Colo., except that the rain-fall is less than half. The topographical variation is not great in Nevada, the summits of the mountain ranges are rarely more than 2,000 or 3,000 ft. above the surrounding deserts. Inyo county, Cal., is different, being remarkable for deep valleys and high precipitous mountains. The altitude of Owens Lake is 3,575 ft., and the Sierra Nevada, a few miles west, reaches an elevation of 15,000 ft., above sea-level. The Panamint peaks rise to 11,000 ft., while Death valley, opposite these peaks, and but a few miles east, is below sea-level. On the west, the Panamint valley is 1,100 ft. above tide, while Saline and Butte valleys are not far from sea-level. Roughly speaking, 600 ft. in elevation is equivalent to 1 degree in latitude; moreover, a deep valley has not the circulation of air that prevails on the table-lands. Hence this is a region of extremes of wind and calm, heat and cold, both diurnal and annual. The storms of winter seem to blow through one and to take all warmth away; yet on a summer day, without any shade, down in one of these deep valleys protected by high mountains from the prevailing winds, it is hotter than in any other part of the American continent. The maximum temperature at Furnace Creek ranch, in Death valley, is said by those who live there to be 127° F. The extraordinary amount of detritus brought down through every little mountain gulch indicates terrific cloud-bursts.

Life would not be so intolerable in these valleys in the summer season if our people would learn more of the Mexicans. Americans even go across the border into Mexico and farther south with their light board houses, low ceilings and thin roofs. Thick stone or adobe buildings with high ceilings and thick or double roofs are always comfortable. The good climate of the whole year in Tonopah and Goldfield is much appreciated by the mining men who have come from the tropics, from Alaska, British Columbia, and from the higher altitudes of Colorado.

Montezuma mountain, 8 miles west of Goldfield (altitude 8,000 ft.), is ever green with piñon and scrubby pine, with a little cedar and juniper around the edges. (It is remarkable how closely one can estimate the elevation through the entire

Rocky Mountain region by noting the vegetation.) The Montezuma Mountain timber-belt extends SW. to the White mountains and to the Fish Lake range. The north end of the Grapevine range is also covered with timber. Cord-wood sells in Tonopah and Goldfield at $16 per cord; at Bullfrog the price is $25. Below the timber there is considerable sage brush, with a few cacti and some yucca palms, locally known as Joshua trees. The desert is often green with several varieties of desert brush having different local names,—a short stunted growth of no value which gives the valleys the appearance of being more fertile than they really are. A strange feature is the almost entire absence of grass. At the head of the Amargosa and southward, "creosote" brush and other desert growths are the same as one sees in northern Chihuahua, western Texas, and in New Mexico, which is good grazing country. Old-timers say that this was not so once, but that several years ago a drouth killed all vegetation that could be used as fodder. Along the water-courses, such as the Oasis valley, at Ash meadows, in the Death valley, Panamint, and others where there is water, salt and wire grass present a meadow-like appearance, but will barely keep cattle from starving. Along the water-courses, willows, cottonwood, and to the south, screw-bean and mesquite, grow. The latter, which is an excellent fuel, is by common consent left to the Indians. Sometimes there are in the valleys large areas devoid of vegetation, with the ground so hard that a wagon leaves but a slight track. Along the low ridges the wind has blown away the soil and arranged the pebbles so as to appear like a mosaic.

The traveler usually takes the "Overland Limited" to Reno, Nev., then the Virginia and Truckee railroad 41 miles to Mound House, the Carson and Colorado 137 miles to Sodaville, and the Tonopah railroad 66 miles to Tonopah. The Carson and Colorado is a narrow-gauge road with light rails and limited equipment. It was completed to Keeler, Inyo county, Cal., in 1881, and was a barren investment until lately, when the Southern Pacific Co. obtained control of it, just in time to reap the benefits of the Tonopah rush. During the past winter this road has been swamped with freight. For 6 months there were from 500 to 1,000 cars awaiting trans-shipment in the various yards near Reno. From Sodaville to Tonopah is

also narrow gauge. From Tonopah to Goldfield there both stages and automobiles are running,—the latter making the distance of 27 miles in 2 hours. All this will soon be changed, and the traveler will be able to leave the main line of the Central Pacific in a broad gauge car that will take him through to Goldfield.

Surveys have been made and there is much talk of railroads from the south. A factor in this situation is furnished by the large deposits of colemanite (calcium borate) between Amargosa and Death valleys. A railroad-route presenting no special difficulty runs from Vegas on the "Clark" road to Goldfield, via Beatty. The distance to Ash Meadows is 90 miles; thence it is 45 miles up the valley to the Bullfrog district and 35 miles diagonally across (south) to the most developed of the borax-mines..

The outfit for a trip through this section requires, as a usual rule, 1 lb. each of vegetable and animal food per day per man, and 14 lb. of hay and 12 lb. of grain per horse per day. A larger amount of alfalfa, with a smaller amount of barley, can be fed. Mules are preferable to horses, because they are more hardy and eat and drink less. In a country where evaporation is so great (an acre of tanks will evaporate 1,700 gal. per day), a team of horses will require about 15 gal., say 120 lb., of water per day; in the heat of the summer more. Where there is running water in the winter there is nothing but a dry "arroyo" in the summer, indeed, in a channel where there is a stream of running water in the morning sufficient for stock, it may be dry and even dusty at sundown.

A good assaying-equipment sufficient for 1,000 assays will weigh 500 lb. and require 5 cases of gasoline. A portable balance, sensitive to 0.005 mg. can be had, and is best in that it enables one to reach a desired degree of accuracy with less fluxes and smaller weight of crucibles.

The people are very kind about giving information as to water and roads; but such information is often inaccurate. Nye county, Nev., has had sign-boards put up at cross-roads; and some of the freighters, also, are thoughtful enough to leave some mark or sign.

From Vegas to Ash Meadows.

For about 90 miles the road follows a succession of desert valleys. The Las Vegas mountain, north, and the Charleston mountain, south, both of Carboniferous limestone, are little disturbed, but the small spurs west are considerably contorted. About 12 miles NE. of Ash Meadows, north of the road, the limestone beds are tilted and underlain by quartzite; and a little south of the road there is a small area of basaltic lava which has overflowed a recent volcanic tuff. For a distance of from 2 to 20 miles SE. of Ash Meadows there is considerable quartzite. Although prospectors report some lead and copper, the region is unattractive on account of the absence of eruptive rocks. On the NW. slope of Charleston mountain are too old mining districts, the Montgomery (now known as the Johnny) and the Stirling. These districts, abandoned for some years, have now taken on new life. The ore is gold-quartz with a little pyrite and chalcopyrite.

The Amargosa Desert.

This desert valley is about 100 miles long and forms with Death valley a long narrow U, extending NW.–SE. The upper end, 4,000 ft. above sea-level, is formed by the joining of the Grapevine and the Amargosa mountains; the former is the northern boundary of Death valley and the latter contains the Bullfrog mining region. The Amargosa is cut through by the Oasis, a narrow valley in which are numerous springs and a little running water. Opposite the Oasis, the Amargosa is 12 miles wide; farther south it widens rapidly. Between the mouth of Forty Mile cañon and the Funeral range it is 30 miles wide. Here the road is so dry and sandy that freighters have to "double," and then can only travel at half the usual rate of speed. The roadside-graves and skeletons of draught-animals are mute witnesses of the hardships here experienced. An enormous sand dune shows that the contour of the mountains has some peculiar effect upon the winds.

Forty-five miles SE. of the Oasis valley is a series of springs. The general locality is known as Ash Meadows. Here the valley is 15 miles wide from the meadows to the Funeral range. In a distance of 6 miles there are four springs flowing about 50

miners' inches of water each, and a number of smaller ones. The temperature of the water in the larger springs is 76° F. and in one of the smaller ones 94° F. All these waters carry a large proportion of sodium carbonate, a remarkable amount of aluminum, a little borax and a small amount of sulphates. From the southerly spring a stream flows for a distance of from 5 to 20 miles, depending upon the season. Below these springs there are large areas of apparently good meadow-land; but the rushes, salt and wire grass are of little value as fodder.

Pahrump ranch 30 miles SE. of Ash Meadows; and 6 miles farther is the Manse. These ranches are veritable oases; and the extraordinary market which they enjoyed last winter for fodder, vegetables and fruit was a godsend to their owners.

Bullfrog Mining District.

At the head of the Amargosa desert the Grapevine range, 3,000 ft. above the valley east and 7,000 ft. above Death valley west, is flanked east by recent volcanic tuffs. Along the summit occur limestones and quartzites dipping east, and a lime-conglomerate, carrying granite, diorite and quartz, such as occur many miles north.

The Amargosa range, lying between the south end of the Ralston desert and the NW. end of the Amargosa, is formed by series of tuffs superimposed upon limestone. The various members of the volcanic series occur with the regularity of sedimentary strata, and the upper (consequently more recent) ones are highly colored. They dip from 10° to 20° NE. An extensive block-faulting has exposed the edges of the various flows, particularly from the west, the escarpment being on that side. About 2 miles west of the Bullfrog mine is a small hill of gneiss, overlain by strata of chloritic slates, quartzites, limestones, and tuffs, dipping flat to the east.

On August 10, 1904, two claims were located as Bullfrog No. 1 and No. 2. From August 10 to September 14, 1904, a large number of claims were located on what are now known as Ladd and Bonanza mountains, about 3 or 4 miles SE.

The Bullfrog Mining Co. was formed to take up a group of Ladd Mountain claims; and later, the first discovery of the district was transferred to a new corporation, The Original Bullfrog Mining Syndicate. A mile south of the original Bullfrog

property some claims were staked off, surveyed and sold as lots under the name of "Bullfrog town." Amargosa, a mile further south, aspired to be the metropolis. Out on the desert west of Ladd mountain the same thing was done; and the "town" was named Bonanza. Four miles from the latter place, in the Oasis valley, on the bank of a stream of running water, the town of Beatty, named for a ranchman living a mile above, was laid out, and soon became the most populous place. Three miles below Beatty a group of tents bore the name of Gold Center. In March, 1905, in a cove made by the desert in the Amargosa mountain, between Bonanza and Ladd mountains, Rhyolite was laid out, and Bullfrog and Bonanza moved to it. This place is 5 miles from water.

About 10 miles SW. of where Oasis valley breaks through the Amargosa range, the cliffs are of limestone which pitches west and is soon buried beneath the soil and the volcanic tuffs that have probably borne it down. In several places the contact is exposed and there are evidences of a flow of water not accompanied by a siliceous deposition, except in and near the Bullfrog claims. Between Ladd mountain and the Oasis creek there is a place where there has been a considerable spring on the contact. Boulders of granite 3 in. in diameter are scattered over an area 100 ft. square. There is no silification and no mineral. The Bullfrog claims cover an immense outcrop that can be seen for miles, and are only 3 miles from a spring that has been frequented by prospectors for 30 years or more. The white quartz lies like a crescent around a small dome-shaped hill, following the contact which dips 30° N. 60° W. into the hill. This quartz has a maximum thickness of nearly 100 ft. and is generally massive, though sometimes there are large slightly amethystine-tinted crystals with a conchoidal base. A later cracking has occurred and a flow of water depositing copper sulphides and the precious metals. Wherever a green stain occurs visible gold can usually be found.

The other properties of this district are entirely different, resembling somewhat those of Goldfield. There has been a nearly vertical fissuring, followed by a flow of water heavily charged with silica, filling the fissures and soaking into the country-rock. One can find all gradations from pure quartz to slightly silicified country-rock. These are the so-called rhyolite

dikes. The country-rock itself had a slight mineralization, which this silicification did not increase. A secondary and much less extensive cracking and inflow of siliceous waters occurred, which deposited the gold. The veins are nearly vertical, strike N. 10° to 30° E., are sometimes thin seams, sometimes several feet in thickness, and again wide zones of stockwerk. The better formed are calcareous and slightly stained with manganese. There are many of these veins and they were easily found; but to discover ore-shoots in them is quite a different matter. The amount of work done in both this district and Goldfield during the past winter has been remarkably small.

An interesting and to the prospector a very important phenomenon is the covering of these veins. The older tuffs are mineralized and the more recent (upper) are not; the older are basic, while in the upper there is a flow of rhyolite. At Tonopah it is quite noticeable that the rhyolite is more recent than the "mineralized porphyry." The regularity of the eruptions and the exposure of the edges of the often highly colored strata make this an ideal place to study this phenomenon.

Funeral Range.

The Grapevine and Funeral ranges are practically the same. Old-timers do not agree as to the dividing line. With the mountains south, they form the eastern boundary of Death valley. There has been much searching in this range for the lost Breifogle mine, one of the romances of the desert. Except in one place, both ranges are poor prospecting-ground. The general formation is quartzite and limestone overlain by immense deposits of recent conglomerate. In the north end of the Funeral range there is a development of green shales, identified elsewhere as Cambrian. These shales usually carry white glassy quartz, which is rarely mineralized; but in this case there are ore-shoots, carrying sufficient gold to make the district attractive if wood and water were more available. One property has recently been thoroughly developed under bond in this district.

To the south the range ends abruptly, near where the wagon-road from Ash Meadows to Furnace creek crosses. The division along the dry water-courses followed by this road is re-

markable; they have large boulders of quartzite and limestone north, and on the other side black and brown lava. South, the topography is broken and mountainous, but not in a distinct range. The Green mountain still farther SW. is another field for prospectors. One small stamp-mill is running at the foot of this mountain on the Death valley side. Still farther south, the drainage of the Amargosa cuts through into the Death valley.

Goldfield.

The tuffs (andesite) of this district probably lie upon limestone, elsewhere identified (*e.g.*, at Bullfrog) as Cambrian. On the southwest side of Columbia mountain is an outcrop of dark limestone, evidently overflowed by eruptives. In the Tonopah Club claim the ore is a siliceous sedimentary that has the appearance of limestone, through which gold-bearing solutions have percolated and left enough of the precious metal to make it possible to sort out some shipping-ore.

The country-rock shows more mineralization than in the southern district and has been much more disturbed since the mineral deposition. There are three large intrusions of alaskite, and a great many dikes of a green rock, probably decomposed trap, which is closely associated with the original andesite. Standing upon one of the intrusions, Vindicator mountain, one can see, both from the workings and the color of the country-rock, that the mineralized area takes the form of a ring. It is yet a question whether the central part will prove of value or not. Outside, the field is completely surrounded by more recent tuffs, overflowed on the west side by dark basaltic lava, which forms a mesa some 4 miles square between Goldfield town and Montezuma mountain.

The topography presents simply hills with higher hills or low mountains around them, except to the north, which opens out to the San Antonio desert. Montezuma mountain (altitude 8,000 ft.) is 8 miles west. The old Montezuma lead-silver district is on the west slope of this mountain. The castings in the 10-stamp mill and 36-in. water-jacket furnace bear the date of 1886. At Lida, a boiler front recently re-set was cast in 1866.

A very prominent geological feature is the reefs of silicified country-rock, usually called rhyolite dikes, found all over the

district, but more numerous to the south and east. They are sometimes very large (50 ft.), but generally about 10 ft. thick; and they extend in all directions without regularity, frequently crossing each other. They are sometimes 2,000 or 3,000 ft. long, and again but a few feet, and exhibit all grades of silicification. On the surface they are hard and flinty; but underground, away from the weather, the rock, although harder than the andesite, which is quite soft, is not bad for drilling. The phenomena of blackening, so noticeable in the desert and recently described by Prof. Blake,[2] is very apparent.

The gold was deposited by successive flows of water in or near these reefs, as was the case with the dikes at Victor, Colo., but there are exceptions, as in the Velvet and Tonopah Club claims. Again, as at Cripple Creek, one often hears that the country-rock shows value, and not the veins. At the surface the gold is very free and is fine in both grain and grade. Below the zone of oxidation, the ores are not yet thoroughly understood. There is probably considerable difference in the different properties. It is now certain that tellurides are present; but the principal accompanying mineral is, as usual, pyrite. Although there is no copper-stain near the surface, there is considerable gray copper at depth. There is rather more antimony than arsenic, but both are present.

It is too early to say what will be the solution of the metallurgical problem. The low-grade ores, of which so little is known now, may be more simple in their composition. The Combination Mines Co. has provided plates, concentrators and a cyanide plant.

It is not at all easy to find the small rich streaks and lenses of ore that have given Goldfield its celebrity, and there is as yet no incentive to develop the low-grade or milling-ores, which will later be the important ones. The charges for freight and treatment are now $32 per ton.

The Jumbo was sampled many times and "turned down." It was bonded and a shaft was sunk, with no results. On the Quartzite, a shaft was sunk and trenching done, and the property was given up. On November 10, 1902, H. Stimler and W. A. Marsh camped at Rabbit Spring, where Goldfield now

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[2] *Trans.*

gets its water, and soon after made locations in the Sand Storm section. In the spring of 1904, the Sand Storm and Kendall claims were carefully explored, with no results. In the Jumbo, gold was found by panning the soft rich country-rock close to the reef which was rich; but the vein was found later *in* the the reef, through which it takes a zigzag course.

After the incorporation of the Jumbo Mining Co., leases were let for the last seven months of 1904 according to the custom of the district, in blocks 200 ft. long by the width of the claim, royalties being set at 25 per cent. of the gross yield. These leases yielded over $1,000,000. The best piece of ground, 200 ft. long and 200 ft. deep, yielded in round figures 2,000 tons of $350 ore and 3,000 tons of $50 ore. The Quartzite and the Sand Storm are now among the active shippers. One lot of 14.5 tons from the Kendall claim of the Sand Storm group, yielded on the plates of a stamp-mill $45,785, and is said to have left tailings valued at $1,000 per ton.

The Combination Mines Co. is the only corporation in the district that is carefully preparing for regular future production. Good buildings are under erection, a pipe-line has been laid 10 miles to a spring, and a well-built mill has been completed. The principal vein is parallel to that of the Jumbo. Just to the NW., on a cross-vein, is the January, which has a dump of several thousand tons of milling-ore awaiting treatment. The Florence mine, one of the best, is on another cross-vein E. of the Combination. This group of four mines is the most important in the district.

Four miles north of Goldfield town is Diamondfield, about 1 mile N. of which occurs another group of promising mines from which some shipments have been made. One of these is the Black Butte, a prominent topographical feature. On this property has been developed ore of probably the lowest grade ($20) mined in the district. A short distance north, on the slope of the butte, is the Quartzite "fraction," one of the most promising properties now shipping ore. Half a mile N. is the Vernal, which has also shipped some ore. To the northwest are two very strong quartz-reefs, in which very limited prospecting has not yet developed any important ore-bodies.

The explorations near the Sand Storm, 3 miles W. of Diamondfield, and a little further from Goldfield, have not been

specially fortunate, except in the Tonopah Club, which is in the low ground between Diamondfield and the Sand Storm.

Northeast of Goldfield town some important discoveries have been made; and ore has been shipped, notably from the St. Ives, a claim covering a very prominent reef near the Jumbo, and from the Cimerone. The latter was found during the summer of 1904, and the finder literally camped on it, putting his tent and bed over the rich place, until he had succeeded in buying the fractional claim from the original locator. Then he made the discovery public, and, in a few weeks, sold out, it is said, for $60,000 cash.

In March, 1905, the town of Goldfield, lying between the Combination mine and the mesa at the foot of Montezuma mountain, had an estimated population of 10,000, and Columbia, practically an extension 1 mile NW., had 2,000, and Diamondfield about 500. Goldfield and Columbia are supplied with excellent water by two 2-in. pipe-lines. The water comes from under the mesa immediately west. The Combination Mines Co. has a pipe-line from the Warm Springs. Twenty miles west of Goldfield is the Silver Peak marsh, where there is an open lake.

Both at Bullfrog and at Goldfield the situation is somewhat discouraging. In March last, scarcely 50 men were working at Bullfrog, and about 200 at Goldfield. While actual development was thus neglected, the industry of transferring to new corporations groups of claims, good, bad and indifferent, of selling the stock of such corporations, was active. All American mining districts have passed, and will doubtless hereafter pass, through such a period.

Tonopah.

The veins in this district are much stronger and more condensed and possess the regularity of silver-veins which they should be deemed to be, since the values are about two-thirds in that metal. The railroad has only been in Tonopah a year, and has been overwhelmed by freight for the newer districts. One small mill, owned locally, is operating, the owners of the developed properties do not seem to think that the time is yet ripe for large reduction-plants.

About 1,500 tons of high-grade ore is shipped weekly to the

smelters, and incidentally an enormous amount of milling-ore is blocked out. It is said that one company has $35,000,000 in "positive ore." In one of the mines 60 ft. thickness of $28 ore is reported. The maximum depth reached is 1,000 feet. This district has therefore long passed its doubtful stage.

The country-rock is andesite, so overflowed by more recent volcanoes that very little of it is exposed. The explorations of the past year have gone through this overflow and found ore by drifting in the "mineralized porphyry" below.

The development of milling, always an expensive and interesting problem, will be unusually so in these three districts. Their ores, though different, are all typically milling-ores, consisting of quartz with very little base metal. Should smelting be necessary, there are several flux-producing districts, now idle, which could be drawn upon.

Borax-Deposits.

South of the Funeral range, in the region drained by Furnace creek and on the Amargosa side of the mountain, is a large development of recent sedimentaries—shales, clays, sandstones, and thin sheets of gypsum. There are a few intrusions of later andesite, and a heavy flow of black and brown basaltic lava. In these sedimentaries immense deposits of calcium borate occur, conformable with the strata. The most common mineral is colemanite. As one might expect from an element possessing the peculiar solubilities of borax, there are many combinations of boric acid, lime and soda under various mineralogical names. There is some question as to the origin of the deposits. The Pacific Coast Borax Co. first obtained title under the placer-law, but now favors lode-locations. That company has the region pretty well "corralled" for borax. The rocks are highly colored. The country is bare of vegetation, and water is scarce.

The borax-deposits are remarkable in size and purity. In one place there is an outcrop of calcium borate 30 ft. thick. At the Lila C. mine on the Amargosa side of the range, 35 miles from and in sight of Ash Meadows, is a deposit, from 3 to 17 ft. thick, dipping about 45° E., and explored on the surface for a mile. The underground workings are in the vein (?)

for a quarter of a mile. This is the property that will bring a railroad to this section.

Death Valley.

Much has been written about this valley, and a strange amount of romance is attached to it. The prospector could easily find a more promising field and a less expensive place to work a mine in. It is a long narrow valley, very deep and surrounded by high mountains. The Panamint and Sentinel peaks reach an extreme elevation of 11,000 ft., while Death valley, hardly 10 miles west, is two or three hundred feet below sea-level. A similar difference of elevation occurs 80 miles NW., between the summit of Mount Whitney and Owens Lake valley.

Under one general name there are three connecting valleys: Death valley proper, Lost valley and Mesquite valley. The upper end of the latter is only about 30 miles from Goldfield. Instead of being the horrible region usually reported, it is the best of the desert valleys. Lying so low and being shut in by surrounding mountains, it is hot in summer; but the winter climate leaves little to be desired, particularly by those who require a dry atmosphere. It is but a few miles west to an elevation in the Panamints, where in the shade of the pines the traveler can be comfortable, and look into the sweltering valley below, while a battery of abandoned charcoal-kilns might make him fancy he was summering near Lake Superior.

The name Death valley comes from the loss of an emigrant train in the lower end of Lost valley. The party was on the way from Salt Lake to southern California, and, becoming exhausted, stopped to rest in what appeared to be a meadow. The salt and wiry grass is not nutritious; the water is saline and carries enough sulphates to disarrange promptly the human digestive system. The spot, where it is said about 50 people perished, has been dug over for buried treasure; and last winter many of the pits were in brackish water. Some prospectors, also, have lost their lives in the south end of the valley.

At the mouth of Furnace creek the Pacific Coast Borax Co. maintains a ranch, having 200 acres in alfalfa and wheat. Twice a month a 16-mule team arrives from Dagget, 160 miles away on the Santa Fé Railroad. Three miles from the ranch are the old Coleman borax-works.

Furnace creek and several streams south, usually dry, bring down borax in solution. For a few miles in width and a length of about 30 miles, the lower part of this valley looks like a mud-flat with the tide out. These places are locally called marshes, although they have no vegetation. The borax is here a double borate of lime and soda, commonly called "cotton-ball."

A peculiar phenomenon, better seen in this than in the other valleys, is the "self-rising ground." The soil carries a large proportion of soluble salts, sodium carbonate, sodium chloride, and various sulphates and borates. Evaporation is excessive; the subsoil is moist, being constantly supplied by springs; and capillary attraction brings the salts to the surface. This does not go on evenly, but forms hummocks, sometimes 2 or 3 ft. high, hard on the surface and soft beneath, making a bad and sometimes dangerous ground to walk across. The same natural laws have caused the surface-enrichment of some mineral-veins in the desert, particularly veins of copper-ore.

The atmosphere in the valley is remarkably clear and possesses the resonance so noticeable above timber-line. There is no truth in the story about birds and animals dying in attempting to cross the valley. The Indians and the Borax Co. keep several hundred head of cattle and some mules and horses about the mouth of Furnace creek; and rabbits, quail and other small game can be found.

Panamint Range.

This range is unusually high and precipitous, starting at sea-level instead of several thousand feet above, as most other high ranges do, and having no foot-hills. The rock is green slates, mica schist, quartzite and limestone. On the west side is an intrusive granite which has tilted the whole formation, the larger part of it to the east. The green slates carry fine-looking quartz; but so far it has not been found to carry values. On top of the range are large areas of recent conglomerate and basaltic lava.

Panamint City once had 6,000 people and is now reduced to a few old-timers, who say it will soon start again and make "the greatest camp on earth." The ores are of silver—refrac-

tory and heavy, with a pyritic gangue. The railroad is 90 miles away.

On the west side of the mountain, every gulch for 46 miles has some sort of a mining equipment, usually a small stamp-mill, idle and owned by some Los Angeles company. The first question asked of strangers, is "Are you from Los Angeles?" It is best to answer, "No!"

Lead-Mines.

South of the Amargosa there are some lead-ores and two large deposits of iron-ore. They are too far from a railroad to have anything but speculative value.

The mountains between the Panamints and the Sierra Nevada were once the scene of great activity in lead-silver mining. Old roads constructed at great expense, smelting-plants at the mines, and charcoal-kilns many miles away in the timbered mountains, are mute evidences of this former scene of activity.

Cerro Gordo, Darwin and Modock produced between 1870 and 1880 approximately $25,000,000. The first-named was the heaviest producer, furnishing the largest quantity and lowest grade of ore, while the last produced the smallest tonnage and the highest grade. They are all at or near the contact of granite and limestone. Unlike the deposits at Monarch, Colo., along a similar contact, these ore-bodies are from a few feet to 300 ft. away from the contact, in cracks and crevices of the limestone.

At Darwin there is an anticlinal about 6 miles long, the west side of which dips about 45° and the east side more steeply. The latter carries some copper, while the former shows none. The oxydized surface ores contain roughly 1 oz. of silver to 1 per cent. of lead, and the galena ores 2 oz. of silver to 1 per cent. of lead. From the old books left at some of the works, it would appear that the average ore contained from 40 to 60 per cent. of lead. The gangue is iron and lime, with some silica. There are four smelting-plants near this place, one of which is in good condition; and 20 persons are still living in the town.

The "on dit" of the country is that the ores became too poor to work at a depth of 800 feet. While these mines were working, Mojave, Cal., was the nearest railroad point, and wood

and charcoal had to be hauled long distances. From the charcoal-kilns in the Panamints to Darwin is 50 miles. The altitude of the kilns is 8,000, that of Darwin 6,000, and that of the intervening Panamint valley 1,100 ft. above tide. The price of fodder must have been high. The nearest farms are now 50 miles away.

Cerro Gordo is 7 miles from, and 8,500 ft. above, Keeler, the terminus of the Carson and Colorado railroad, 334 miles from Reno and, by wagon-road, 120 miles from Mojave. Here are located the soda-works of the Inyo County Development Co. With diminished treatment-charges at custom-smelters, lower rates of freight, and the flood of siliceous ores now going on to the market, it would not be surprising if these lead-ores, with their useful fluxing character, should be again mined with profit.

Owens Lake Valley.

Owens Lake valley, about 75 miles long and 20 wide, is drained by Owens river which flows into the lake of the same name, about 18 by 12 miles in area. The water of the lake is a nearly saturated solution of sodium carbonate and common salt, with a little sulphates and borax. There is no verdure around the edges.

The river is fed by streams from the west, having their origin in the Sierra Nevada, a very high, snowy and well-timbered range. All the older settlements are on these streams, but the railroad follows the east side of the valley. A large ditch has been carried by an irrigation company down the east side of the valley to within 12 miles of Keeler; and the new comers are settling along this ditch.

While the valley is fertile and well-watered, particularly at the north end, the farmers have not as a rule been prosperous, because the market was too distant. Now a sudden change has come. From Laws station, opposite Bishop, in the upper end of the valley, to Tonopah is 113 miles by rail. It is fortunate, both for the farmers and the miners, that there should be an agricultural region so near.

All the streams coming from the Sierra Nevada furnish opportunities for developing water-power, already a company is preparing to generate and transmit electric power from Bishop creek to Tonopah and Goldfield.

All the grains and fruits of the temperate zone are raised here. The apples, peaches, pears and certain varieties of grapes, are better than those raised on the Coast-side of the Sierra.

Smaller Mines Tributary to Owens Lake Valley.

In the south end of the Argus range and in the Coso mountains are many veins, usually only a few feet in width, of white quartz in granite, occasionally carrying gold, low in value and in spots rather than in regular ore-bodies. Most mining men dislike these conditions. The Congress mine in Arizona is the only large and successful enterprise working this class of quartz.

The Beveridge and Lee districts, NW. of Darwin, have argentiferous ores. At the latter place there was formerly a stamp-mill, which, judging from the amount of tailings, did not run long.

The Ubaheba district, lying between the Saline and Butte valleys, is a large undeveloped region of low-grade copper-ores, in contact-deposits between limestone and some acid eruptive. These valleys are very deep, and would be a continuation of the Panamint valley but for an east and west mountain that looks like an enormous dam. The west end is granite; but the larger portion of the mountain is recent conglomerate overflowed by basalt.

In the mountains facing Owens Lake valley on the east side, both in the granite and the chloritic slates, quartzites and limestones, which the intrusive has thrown on edge, there are numerous veins of white quartz, carrying occasional gold-values.

Between the stations of Alvord and Citrus, 3 or 4 miles from the railroad at the foot of the mountain, and well located for economic reasons, is a new stamp-mill and out-buildings, now idle.

Farther up the valley, at Poleta, there is a plant running.

From Owens Valley to Goldfield.

From Alvord station, 5 miles from Big Pine, 20 miles from Bishop, and 54 miles by rail from Keeler, there is a wagon-road, 61 miles to Lida, and 96 miles to Goldfield. This road is now much used by freighters and farmers hauling produce to Lida, Goldfield and Tonopah. Three ranges of mountains

and two valleys are crossed. Between the Deep Spring and Fish Lake valleys there is a gold-copper exploration near the road. In the mountain east of Fish lake are two old mills.

About Lida, and between Lida and Montezuma mountain, the formation is light-green slates overlain nonconformably by limestone. In the slates are dikes of porphyry and rhyolite, and many quartz-veins. At Lida the veins are exposed on the surface and show remarkable persistence in length; but when worked 30 years ago, they were found to lose their values at a depth of from 200 to 300 feet. The ore is quartz with little galena and zinc blende. The principal values are in silver.

From Lida east to the Kawich range the rocks are all volcanic, from rhyolite to basalt inclusive, but rarely are there any of the earlier tuffs or andesites.

Gold Center is a small area, similar to Goldfield, but the ores are not particularly high-grade or continuous. The soft aluminous country-rock seems to have moved too much after the ore was deposited.

Quartz Mountain, 24 miles south, is of rhyolite, with veins similar to those of the Bullfrog district.

It is remarkable that so many mines have been found of late years in the volcanic tuffs, now generally known as andesite. A very large portion of them carry gold. One cannot but wonder if there are not more. This is not a formation which prospectors have liked until lately; and as yet it has been but imperfectly studied. The fact that the mineral-bearing tuffs are basic, and are overlain by the acid rhyolite, is perhaps significant. Cripple Creek has a rhyolite mountain in which much money has been spent without satisfactory results. The nature of the veins, too, is new. They may often be called freaks. Mineralizations of country-rock are to be expected rather than "text-book" veins, such as used to be sought for.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Cost-Accounts of Gold-Mining Operations.

BY THOMAS H. SHELDON, VICTOR, COLO.

(Bethlehem Meeting, February, 1906.)

In the zeal for opening up new ore-bodies, or for extracting the ore from attractive bodies already opened up, we very often lose sight of the fact, that, after all, the operation of a mine is a business proposition, pure and simple; and for the best working-results should be treated upon a strict business basis. Of course, in every mine of consequence a record is kept of expenditures and receipts, and such glittering generalities as "gross receipts," "net receipts," "mining expenses," and "per cent. profit," can be told to the cent; but does this record show economy of management, either as compared with the same record of other months, or as compared to the record of other mines of the same class? Moreover, if such a record shows that the cost of mining is high, does it in any way enable the manager to put his finger on the leakage? Does it necessarily follow that a mine which makes a profit of, say, 40 per cent. on 25-dollar ore, is doing less economical mining than one which saves 60 per cent. on 80-dollar ore? Of course the figures in the latter case look the more attractive, but when it comes to a point of saving everything which can be saved, and of cutting down expenses to the lowest possible cost of operation, the former mine is doubtless on the most firm and economical financial basis. But as the relative merits of the system of mining in the two cases, nothing could be decided without a basis of detailed comparison; if one system is more economical than the other, why is it so, and wherein does the advantage lie?

This can be shown only by keeping accurately the cost of each mining operation. And no matter how dissimilar two mines may be in character and operation, yet there are a few general heads common to all mining operations. In the first place, it is necessary to break the ore from the solid ground;

then it must be transported from the place where it is broken to the place of concentration (if any)—and this transportation generally includes two operations, underground tramming and hoisting; and lastly, there is the cost of extracting the precious metal from the ore (and, generally, of transportation from the place of concentration to the place of extraction). In addition, there are accessory costs, such as timbering and pumping, and general costs, such as supervision, sampling and surveying, and such expenses as cannot be included in any one of the general heads above, but are part of the cost of operation and should be apportioned among those heads. Then, too, there are the costs for exploration, and for equipment.

All expenses must be shown, not by themselves, but in regard to their direct effect upon the ore mined, and all can be shown in one way or another to be tributary to one of the general heads mentioned. For instance, it is a very interesting fact to know just how much it costs to run the boiler-room, but the steam generated has no direct effect upon the ore, but only through the hoisting-, compressing- and pumping-engines; so it is much more essential to know the value of the steam used to break the ore, to hoist it, and to keep the mine dry enough to work in.

To show its relative efficiency, each department should have an account kept, wherein it is charged with all the debits which make up the cost of its operation, and credited with its proper contribution toward the whole general result. In other words, a double entry system of book-keeping is desired, where each operation, such as breaking ore, tramming, hoisting, etc., has its debit and credit account.

There are many methods of keeping these accounts; the ordinary book-keeping method is too clumsy, being too laborious in operation, and defeating the very object for which it was intended by taking up too much time and trouble on the part of the management in inspecting and studying the various accounts in their relations to each other. The card system has many adherents, and it is certainly an excellent plan for keeping the individual accounts which go to make up the cost-keeping system; but it is open to the same objection, in not showing at a glance the relations of the accounts to each other, to the whole result, and to the average cost, so that any leakage may

be readily discovered, located and properly remedied. And this is the need ot the modern mine-manager.

This need has been met in the system now used by the Portland Gold Mining Co., Cripple Creek, Colo., which is applied in its simplest form—that is, the marketable product is only gold which always has a market value of $20 per ounce. The mine is of large size, and there are numerous details to account for; therefore it is the purpose of this article to describe that system at some length, as being a typical and representative case of its application. The figures shown herewith are those published in the company's annual report for the year 1902.

In brief, all the operating costs are represented upon one large sheet by co-ordinate methods; debits being figured along the line of abscissæ and credits along the line of ordinates. Thus, every figure is viewed in two relations: as a credit and as a debit. It is a credit to the account heading the vertical column under which it falls, and a debit to the account in the horizontal column opposite. The horizontal columns, then, show how the expenses accrue, and the vertical columns show how they are expended.

The accounts are divided into four main heads:—Milling, Plant and Development, Stoping and Distributed Accounts. This last-named does not figure by itself in the operating costs, and its totals are not to be included with the other total debits; but these amounts are distributed or charged out among the other three heads; that is, the accounts which do not bear directly upon mining ore are charged out to those accounts which do. Thus, for example, the total cost of running the boiler-room is distributed or credited to the various purposes for which steam is used, such as hoisting and compressing. The hoisting account, for example (the third line of the distributed accounts, Form 1); the amount we have just found which hoisting is indebted to the boiler-room is added to hoisting's other debits, showing the total cost of hoisting; this, then, is charged out or credited under the head of *Stoping* to the account of hoisting ore, and under the head of *Development* to the accounts of drifts, cross-cuts, etc., on the basis of the tonnage hoisted from stopes, drifts, cross-cuts, etc. Hence, all of the distributed accounts eventually find their way into the three main heads above, to accounts which bear directly upon mining the ore.

MILLING.—Since the Portland mill is not situated near the mine, its accounts are kept separate, and under "MILLING" we have only two items—"total freight and treatment on ore sent to the Portland mill," and "total freight and treatment on ore shipped elsewhere." These two items are kept separate in order to compare the cost of treatment at the company's mill with that of custom work.

PLANT AND DEVELOPMENT.—In this head, the former includes only new buildings or the installation of new machinery—whatever may be considered a permanent improvement—and the latter includes underground operations which are of the nature of permanent equipment, such as a new shaft to facilitate hoisting, a new drift to open up a vein or system of veins, or a cross-cut to explore virgin territory. DEVELOPMENT is considered to embrace only those operations which could be cut off without materially affecting the production of ore. Under this head we find the sub-heads which embrace the total cost of running drifts, cross-cuts, of raising and sinking shafts and winzes. Thus it appears that everything under the head of PLANT AND DEVELOPMENT is an asset. All other costs are charged to stoping, as this is considered to include all ordinary running expenses. These two headings need no further comment here.

STOPING.—This heading deserves further consideration to explain its sub-heads:—

Breaking Ore.—Under this head is included everything from drilling into the solid rock to delivering the ore into the chutes ready for the trammers. It also embraces the labor of the machine-drill men, hand-miners and muckers, the cost for running the machine-drills, the cost for explosives, etc.

Tramming.—The cost of getting the ore from the chutes to the stations of the shafts, including repairs to tracks and tram-cars.

Hoisting.—The cost of raising ore and waste to the surface, delivering the ore to the bins and depositing the waste on the dump; includes the cost of running the hoisting-engines, labor of cagers and skip tenders, repairs to the shaft and machinery, and surface tramming and tram tracks.

Timbering.—The cost of both labor and material used in keeping the mine timbered.

Sorting and Loading.—All expense of hand-concentration; the cost of tramming to the dump the waste picked from the ore, of loading the ore into the railroad-cars for shipment, and of keeping the ore-houses and bins in repair.

Pumping.—The cost of keeping the mine dry; includes repairs to both pumps and lines.

Lighting.—Cost of electric lights and lines, and candles issued to the miners.

Assaying.—Includes cost of mine-sampling.

Surveying.—Everything in the mine-engineering line.

Repairs.—Only those charges for general wear and tear which are not directly chargeable to any of the above heads—such as, for instance, painting the shaft-house.

General Expense.—Office accounts of both the Victor and the Colorado Springs offices; salaries of directors and officials, etc.

Insurance and Taxes.—Amounts paid for insurance and taxes on all mining property.

Litigation.—All legal expense connected with the mine.

Development Charged to Stoping.—Costs of those pieces of exploration work which produce ore in their progress.

The other items need no comment here.

The general cost-sheet is supplemented by two auxiliary cost-sheets: one for stoping and one for development. (Forms 3 and 4.) On one or the other of these is found the cost of operation in detail, as well as the production and progress, of each working place in the mine. These sheets are not entirely separate and distinct from the cost-sheet, but are interdependent each upon the other, as will be more clearly shown later.

The scope of the cost-sheet can be most clearly and satisfactorily explained by referring to an actual example; so reference will be made to the one for December, 1902. (Form 1.) This cost-sheet was published in the company's annual report for that year.

Distributed Accounts.—Taking the first horizontal line,—the item of the boiler-room, we find this account indebted the sum of $99.56 to the machine-shop, $42.89 to the blacksmith-shop, $2.30 to the carpenter-shop, and also $464.92 to the supply account, all of which represent labor and supplies used in repairing and maintaining the steam-lines, boilers and buildings, as well as the supplies, such as waste and oil, for opera-

tion; also to the pay-roll $1,073.25, the labor of the firemen; and to general office account $7.75, a voucher account directly chargeable to making steam. Then we see the account of fuel debited with $5,063.10 by the general office, which sum represents vouchers covering the cost of the coal, delivered in the bins. This, then, appears as a lump sum charged to the boiler-room, showing as a debit to the boiler-room and a credit to the fuel account. So, summing up the debits of the boiler-room, the total cost of making steam appears to be $6,753.57.

The master mechanic's report shows the steam was consumed in the proportions given in Table I.

TABLE I.—*Consumption of Steam.*

	Per Cent.
Pumps and dryers for washing waste rock in ore-house,	5.5
Pumps in mine,	18.4
Heating office-buildings and residences,	2.7
Compressors,	37.8
Hoisting-engines,	27.2
Dynamo-engine,	7.8
Steam-hammer (for sharpening drill steel),	0.6
	100.0

The cost of making steam, $6,753.57, is then charged to the above accounts in the above proportions, and the boiler-room credited to that extent, as shown in Table II.

TABLE II.—*Cost of Steam.*

Boiler-Room,	*Dr.*	*Boiler-Room,*	Per Cent.	*Cr.*
Machine-shop (repairs),	$99.36	Sorting and loading,	5.5	$360.64
Blacksmith-shop (repairs),	42.89	Pumping,	18.4	1,241.31
Carpenter-shop (repairs),	2.30	General expense,	2.7	180.32
Supplies,	464.92	Compressing	37.8	2,561.63
Fuel (delivered in bins),	5,063.10	Hoisting,	27.2	1,840.35
Pay-roll (firemen),	1,073.25	Electric-plant,	7.8	527.45
General office,	7.75	Machine drills,	0.6	41.87
	$6,753.57			$6,753.57

In Table II., the first three credit items are ready to be added in as they stand to form the total operating-costs, as they bear directly upon the ore account; they are now disposed of as far as the distributed accounts go. The other items remain in the distributed accounts, in turn forming debits of other accounts.

The tabulation of other accounts is given in Table III.

TABLE III.—*Cost of Compressing, Hoisting, Electric Plant and Machine-Drilling.*

Compressing,	*Dr.*	*Compressing,*	*Cr.*
Boiler room, steam, ...	$2,561.63	Machine-drills, ...	$2,993.83
Machine-shop, repairs on compressors and air-lines, . .	22.54		
Supplies, oil, waste, packing,	130.66		
Pay-roll, engineers, ...	279.00		
	$2,993.83		$2,993.83

Hoisting,	*Dr.*	*Hoisting,*	Tons.	*Cr.*
Boiler-room, steam, ...	$1,840.35	Stopes (hoisting ore), ...	17,407	$4,118.60
Machine-shop, repairs on engines, ...	34.97	Drifts, ...	1,536	363.54
Blacksmith-shop, repairs on engines, ...	16.95	Cross-cuts, ...	2,439	577.20
Carpenter shop, repairs on engine-room, ...	19.75	Raises and winzes,	373	88.32
Supplies, lubricants, packing, ...	363.08	Shaft No. 1, . . .	66	3.31
Pay-roll, hoisting engineers,	2,886.44	Shaft No. 2, . . .	14	15.57
General office, ...	5.00			
Cost of hoisting 21,835 tons, ...	$5,166 54		21,835	$5,166.54
or $0.2366 per ton.				

Electric-Plant,	*Dr.*	*Electric-Plant,*	*Cr.*
Boiler-room, steam for generator, ...	$527.45	Lighting (mine and surface), .	$914.08
Machine-shop, electrician and repairs, ...	208.85		
Supplies, lamps, wire, etc., . .	177.78		
	$914.08		$914.08

Machine-Drills,	*Dr.*	*Machine-Drills,*	Shifts.	*Cr.*
Boiler-room, steam-hammer,	$41.87	Breaking ore, . . .	1,575	$3,648.71
Compressing, air for machines, ...	2,993.83	Drifts, ...	267¾	620.42
Machine-shop, repairs on machines, ...	203.58	Cross-cuts, ...	365	845.37
Blacksmith-shop, sharpening steel, ...	1,728.13	Raises and winzes, .	66	151.70
Supplies, repair parts and new steel, ...	599.88	Shaft No. 2, ...	10	23.16
		Shaft No. 3, ...	120	277.93
Cost of operating, ...	$5,567.29		2,403¾	$5,567.29
2,403¾ shifts, or $2.3166 per shift.				

An examination of the credit account of the boiler-room, together with the other debit accounts, will show that all the boiler-room expense has now been distributed among the various operating costs. In like manner all of the distributed ac-

counts eventually find their way into the operating accounts, and are there absorbed by the various items under that head.

The final result of the cost-sheet is now merely a question of cross-footing the various operating accounts, and balancing with the line called *Total Cost of Mining*. This gives, of course, the amounts in the total debits column, and summing these up gives the total cost of operating the mine.

The last three vertical columns of the cost-sheet speak for themselves; the figures are obtained merely by dividing the total debits by the tonnage gross, tonnage shipped, and ounces of fine gold produced. These figures, of course, are invaluable for showing the efficiency of the operations of mining, and may be said to be the pulse by which the condition of the mine may be felt at once. Of these three columns, the last should be the criterion, although the cost per ton shipped is more often referred to. But as the same gross result may be obtained by shipping a large tonnage of low-grade ore or a small tonnage of high-grade ore, yet the costs and profits will be vastly different in the two cases; so the cost of producing an ounce of fine gold, regardless of tonnage, is the real criterion. For after all the object of running a gold-mine is not to produce gold-ore so much as fine gold.

It will be noticed that on the cost-sheet shown herewith there are really two cost-sheets in one, side by side; one for the current month, and one for the current year to date—in this case a period of six months, of which the current month is the last. This latter cost-sheet is kept side by side with the other, in order that the current month may be compared at a glance to the rest of that year preceding, and also that the results of a year's run may be readily obtained. These figures are not worked out separately, but are carried forward from month to month.

The basis of the distribution into the heads of *Stopes*, *Drifts*, *Cross-cuts*, etc., is found in the auxiliary-sheets mentioned before. Thus the number of shifts worked with machine-drills to break ore is found from the stope-sheet to be $1,575\frac{3}{8}$, and the number required to run drifts shows on the development-sheet to be $260\frac{7}{8}$, for cross-cuts, $311\frac{1}{2}$, for raises and winzes, 56, and for sinking, 70. This gives a total of $2,273\frac{3}{4}$ shifts. Then on the development-sheet it will be seen there were 130 shifts

worked with large machines; and as these require just twice as much air as the small ones, 130 should be added to 2,273¾, giving an equivalent of 2,403¾ shifts. Now from the cost-sheet the total cost for running machine-drills appears to be $5,567.29, or $2.3166 per shift. This constant, multiplied by the number of shifts for each heading, gives the cost of machines for that place. And thus also for the other costs on the auxiliary-sheets—the explosives and timber being charged out as used, and the other costs being apportioned pro rata according to production.

The results of the cost-sheet, such as the total cost of mining, cost of milling, per ounce and per ton, together with other items of general interest, are plotted into graphic curves. These form very interesting and instructive diagrams, one of which is shown in Fig. 1. The upper line represents the average value of the ore in dollars per ton shipped; the next line below shows the total cost of producing and marketing a ton of ore; the difference between it and the line above representing of course the net profits per ton. The second line is the sum of the two smooth lines below—the cost of mining and the cost of treatment. In the same way the next broken line below, the total cost of producing an ounce of fine gold, is composed of the two costs represented in the lower broken lines—the cost of mining an ounce of gold, and of extracting that amount of the precious metal from the rock. The dotted line at the bottom represents the cost of mining a ton of crude rock. The figures forming the basis of these curves are taken from the cost-sheet.

It will be well to note that the general upward tendency of the costs during October, November and December is due to the installation of new and expensive machinery; while the downward tendency of the mining-costs in December is the beginning of the effect of this machinery. The upward movement of the treatment costs is on account of the higher grade of ore being treated.

At the mine the different sets of curves are shown in different colors of ink. Other diagrams are also kept, such as the cost and progress of development work, tonnage handled and shifts worked.

Comparison with the new cost-sheet form published herewith (Form No. 2), which has recently supplanted the old form

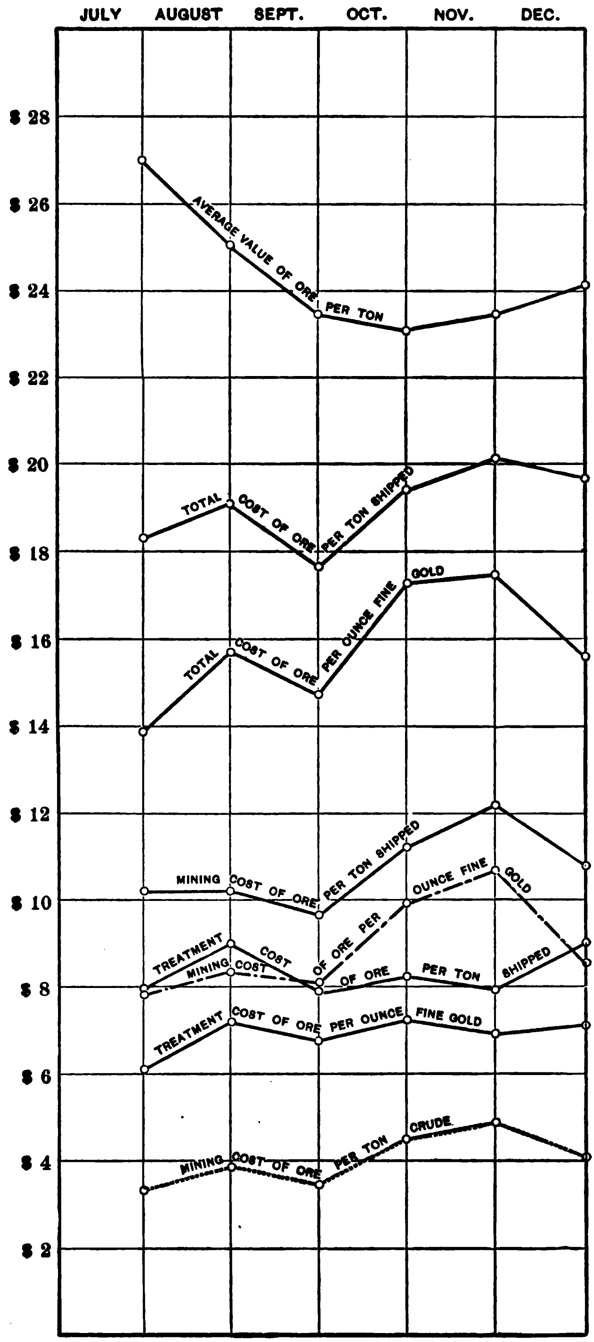

FIG. 1.—DIAGRAM OF OPERATING-COSTS OF THE PORTLAND GOLD MINING CO.

just explained, shows the new system differs from the old only in the greater amount of detail shown, especially in the distributed accounts; the principal of the system remains unchanged. By the addition of a number of lines to the distributed accounts, and corresponding vertical columns, detail can be shown to any extent desired. Greater detail is also obtained by the addition of the four vertical columns headed Shafts Nos. 1, 2, 3, and Lowell. These four columns balance by themselves with the total debits column, but are separate from the rest of the debits. The total debits column, then, is balanced in two different ways: with the four working-shafts, and with the rest of the cost-sheet. Take, for example, the hoisting account. The cost of the hoisting operation for each shaft can be ascertained with great accuracy, also the amount of repairs put upon each engine, thus showing at a glance the relative efficiency of each hoisting-plant. But in the total debits column only the grand total of all the hoisting expense is entered; this is distributed and charged out as before shown in the old cost-sheet. As the shafts, except the Lowell, are all connected underground, the mining-expense cannot always be kept separate, but merges one into the other, so such items as breaking ore and tramming, which do not fall naturally into divisions by shafts, are charged out to the various shafts on the basis of the tonnage hoisted from each.

The addition of the account called "*Invoice*" will also be noticed. As such accounts as supplies, timber, explosives, and fuel are charged out as used and debited as bought, the debits and credits do not balance on the old cost-sheet; by charging this difference to the account of invoice on the new form, the accounts balance, and the invoice account, carried forward from month to month, shows the amount of these articles in stock.

The two cost-sheets are both shown in this article to illustrate how the same system of the co-ordinate method of cost-keeping may be made either general or particular. In the old form the system is a very general one, and could be condensed and generalized even further; while the second form goes into considerable detail, without departing in any essential respect from the main principle.

Such a system of cost-keeping may be objected to on the ground of involving too much "red tape," and therefore being

too expensive in its operation. In reply it is maintained that any system which accomplishes its purpose in keeping accurate record of the cost of operating is cheap at any cost. But the present system is not nearly so cumbersome and expensive as it doubtless looks at first glance. It has now been kept up at the Portland office for nearly three years, with the employment of the same office force as was employed for the same length of time previous to its installation.

To explain just how each one of the basic figures is obtained would be going into a great deal of unnecessary detail, a large part of which would be too local to be of general benefit, as the operation of this system is made to fit the material at hand, and is largely a product of growth. However, a sketch of the every-day labor, as practiced at the Portland, may be instructive.

There are three general heads under which the entire cost of production may be grouped:—first, *pay-roll;* second, *voucher-account*, for supplies and all other expenses which appear on the cost-sheet under the head of "General Office;" and third, *freight and treatment charges*. Theoretically the sum of these three should be the total cost of operation, and on the new cost-sheet it actually is, when the invoice account is considered. The freight and treatment charge is taken in a lump sum directly from the ore-book, and requires no further comment here; so the whole of the cost-sheet has its derivation in the distribution of the other two accounts, the pay-roll and the general office.

The distribution of the pay-roll is accomplished by each shift-boss or foreman making out a report of each day's work upon a regular form (forms Nos. 5, 6, 7, 8, 9, 10 and 11) which shows the number of shifts or hours worked upon any particular job under his supervision. These reports are all handed in to the office at the close of the shift, and the next day are compiled. This then shows the daily cost of each piece of work—the cost of operating the machine-drills, the cost of tramming to the shaft, the labor-cost of timbering, or of putting up a new building. Then at the end of the month it is simply a matter of addition to get the labor-cost of each piece of work done, the total of all, of course, balancing with the total pay-roll. But the cost thus found is not yet ready to go

into the cost-sheet as it stands—there are certain additions to be made to it. For instance, repairs to the machine-shop might necessitate the assistance of a carpenter; the cost of his services is then taken from the carpenter-shop account and charged to the machine-shop; but as it benefits the whole mechanical department, each charge in that department has to stand its share of it. And so, too, with the wages of supervision—this cannot be charged to any particular job, but must be apportioned among all the pieces of work under that supervision. The way these charges are apportioned appears in Table IV.

In Table IV. the first column represents the actual labor-costs as taken directly from the daily reports. Then, grouped under the sub-heading "*Distributed*" are the items, general in nature, which must be distributed over these amounts to make the true costs. The second column shows the distribution, pro rata, of this amount. The figures in the third column are the sum of those in the first two, and are the amounts which are now to be entered directly upon the cost-sheet.

For example, the last line of the first division is the item $7.88 charged against the carpenter-shop. This charge, then, is placed directly against the carpenter-shop, and appears under the sub-heading "*Distributed.*" Then this $7.88, with other similar items, make the $199.08 which is to be distributed over the items forming the total of $1,502.39, or at the rate of about 13.25 per cent. Each amount in the second column is about that percentage of the corresponding figure in the first, and their sum forms the amounts in the third column, which then appear on the cost-sheet.

The distribution of the general office column of the cost-sheet comes from the voucher-record, upon which is kept a distribution of each account as it is vouchered. This form is not shown here, being merely a book similar to that generally used in connection with the voucher-system. These accounts have to be treated the same as those of the pay-roll, as just explained, before entering upon the cost-sheet. However, the supplies-, explosives-, and lumber- and timber-accounts are further distributed. No supplies are issued except upon written order to the store-keeper (form 12), signed by the foreman of the department, and stating the specific use of the article; this forms the basis of the storekeeper's distribution of supplies issued.

TABLE IV.—*Distributed Costs of Machine-Shop and Carpenter-Shop.*

Machine-Shop.

	Pay-roll.	Distributed.	Total.
Machine-drills	$188.50	$15.08	$203.58
Machinery (new)	1,881.88	152.52	2,034.40
Hoisting	32.38	2.59	34.97
Compressing	20.87	1.67	22.54
Sorting and loading	22.50	1.80	24.30
Electric plant	193.38	15.47	208.85
Blacksmith-shop	65.88	....	65.88
Pumping	61.38	4.91	66.29
Tramming	116.25	9.30	125.55
Supplies	233.12	18.65	251.77
Boiler-room	92.00	7.36	99.36
No. 2 shaft	212.75	17.02	229·77
Buildings	14.87	1.19	16.06
General expense	25.00	2.00	27.00
Carpenter-shop	7.88	....	7.88
	3,168.64	249.56	3,418.20
Distributed:			
Lumber and timber	....	1.20	....
Blacksmith-shop	....	1.94	....
Supplies	....	92.92	....
General office	....	153.50	....
Total:	....	$249.56	....

Carpenter-Shop.

	Pay-roll.	Distributed.	Total.
Lumber and timber	$485.43	$62.00	$547.43
Cribbing	101.88	13.00	114.88
Machinery	51.00	6.90	57.90
Buildings	633.70	85.00	718.70
General expense	5.25	0.70	5.95
Sorting and loading	85.38	11.53	96.91
Assaying and sampling	4.00	0.55	4.55
Boiler room	2.00	0.30	2.30
Hoisting	17.25	2.50	19.75
Repairs	6.00	0.80	6.80
Surveying	9.50	1.40	10.90
No. 2 shaft	15.00	2.00	17.00
No. 3 shaft	86.00	12.40	98.40
Total	$1,502.39	$199.08	$1,701.47
Foreman	155.00	....	....
	$1,657.39	....	....
Distributed:			
Foreman	....	$155.00	....
Machine-shop	....	7.88	....
Supplies	....	13.30	....
General office	....	22.90	....
	....	$199.08	....

Explosives are issued by the powder-man only upon an ammunition order from the machine-drill man, stating the heading where it is to be used (form 13). From this data the powder-man makes up his monthly report (form 14). The lumber and timber used is distributed by the carpenter foreman, who keeps account of all the lumber used in repairs and construction about the surface, as well as the underground timbers. The latter account is still further subdivided by the head timber-man, to whom is reported daily the amount of lumber and timber used in each heading by each timber-man (form 15). This gives him data for his monthly timber-record (form 16). At the end of the month the columns are added and figured at a price sufficient to cover cost of framing and handling, as well as of purchase. The amount of fuel used is reported by the master mechanic, who weighs it as it is used under the boilers. The master mechanic also reports the distribution of the steam generated, based upon the horse-power of the engines consuming it.

The basis for the auxiliary-sheets is the shift-bosses' distribution-sheet (form 17), one of which is used for each stope, drift, cross-cut, etc., in the mine, and upon which the shift-boss enters the distribution of his shift. The tonnage from each place is obtained by counting the number of trammers' tags (form 18) from that place, and multiplying by the car-constant (0.7 ton); these tags the trammers place upon the cars as they leave them at the stations, and the top-men remove them and turn them into the office. Of the other costs upon the auxiliary-sheets, the explosives and lumber and timber are charged directly from the powder-man's and head timber-man's reports; the cost for machines is the debit against machine-drills on the cost-sheet, distributed on the basis of the number of drill-shifts worked; the other costs are taken from the cost-sheet and distributed on the basis of tonnage. The column for feet of progress on the development-sheet is filled in by the surveyor.

From the above, it will doubtless be commented that this throws a good deal of clerical work upon the shift-bosses and foremen—which is very true; but there is nothing complicated in what these men are asked to do—nothing that the man with average intelligence enough to be a good foreman cannot do in

20 or 30 minutes at the close of the shift. And this expenditure of time more than pays for itself in giving the foreman a line on his work—a review of the work of the day and a basis for the plans of the next. It is merely a question of devoting about that much time to it every day. By obtaining the co-operation of the foremen, the system is not nearly so expensive as may be imagined.

No progressive and business-like mine-operator will question the efficacy of keeping close watch upon his cost of production—of having some system which will show at a glance at regular intervals where a saving might be effected, and which will compare the efficiency of present working with past. The only question is as to how this can best be accomplished.

While it is not claimed that the system above described is the best that could be devised for all cases, yet it is claimed that it is the best for the conditions here at hand; and it is also claimed that the excellent showing made by the Portland mine in recent times is entirely due to close supervision guided by the cost-sheet.

In conclusion, I wish to disclaim credit for any originality in the system described, except in a few minor details, such as the graphical diagrams of the results. The credit for installing the cost-sheet at the Portland mine (in 1902), and for working out its general ideas, belongs to Mr. J. R. Finlay, then manager; in this labor he was ably assisted by Mr. L. F. Curtis, the purchasing agent, who put the system upon a practical working-basis, and who has since modified it to suit the growing needs of the mine. To these gentlemen, together with Mr. F. M. Kurie, the present manager, I wish gratefully to acknowledge my indebtedness.

FORM 1.—*Portland Gold Mining*

20,425 Tons of Ore Stoped for Month of December, 1902. 121,677.755 Tons Stoped for 6
7,837.19 Tons of Ore Shipped for Month of December, 1902. 47,649.26 Tons Shipped

		Boiler-Room.		Compressing.		Hoisting.		Electric Plant.		Tramming.	
		1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.
OPERATING ACCOUNTS. Stoping.	Breaking ore..										
	Tramming.......									518.92	2,852.93
	Timbering.......										
	Hoisting..........					4,118.60	25,956.40				
	Sorting and loading......	360.64	1,859.86								
	Pumping	1,241.31	19,517.78								
	Lighting..........							914.08	4,526.02		
	Assaying..........										
	Surveying........										
	Repairs...........										
	Gen. expense, Victor........	180.32	712.20								
	Gen. expense, C. S..........										
	Insurance and taxes.........										
	Litigation........										
	Total.......	1,782.27	22,089.84			4,118.60	25,956.40	914.08	4,526.02	518.92	2,852.93
Development.	Drifts..............					363.54	2,787.97			45.21	495.61
	Cross-cuts.........					577.20	1,710.96			72.27	228.41
	Raises..............					88.32	390.72			10.85	58.59
	Shaft No. 1.......					8.31	302.87			0.41	50.90
	Shaft No. 2.......					15.57	15.57			1.91	1.91
	Shaft No. 3.......		323.84								
	Cribbing..........										
	Buildings.........										
	Machinery										
Plant and											
	Total		323.84			1,047.94	5,208.09			130.65	835.42
	Total cost mining	1,782.27	22,413.68			5,166,54	31,164.49	914.08	4,526.02	649.57	3,688.35
Milling.	Portland mill...										
	Other freight—treat...........										

Distributed

DISTRIBUTED ACCOUNTS.	Boiler-room										
	Compressing....	2,561.63									
	Hoisting...........	1,840.35									
	Electric plant..	527.45									
	Tramming......										
	Timbering.......										
	Machine-shop..										
	B. S. shop........										
	Carpenter-shop										
	Machine-drills.	41.87		2,993.83							
	Explosives.......										
	Lumber and timber..........										
	Supplies..........										
	Surface expense										
	Fuel.............										
	General office...	4,971.30		2,993.83							
		6,753.57		2,993.83		5,166.54		914.08		649.57	

EXPLANATION.—All accounts are debited in the horizontal columns opposite
The "Distributed Accounts" do not figure by themselves in
out among the various operating accounts under the heads

Company.—General Cost-Sheet.

Note.—Form 1, the original size of which is 21 by 43.5 in., covers 4 pages of this paper. The left half of the sheet is given on this and opposite page, and the right half on the two following pages.—R. W. R.

Months. 9,888 Ounces Fine Gold for Month of December, 1902.
for 6 Months. 56,996.137 Ounces Fine Gold for 6 Months.

Timbering.		Machine-Shop.		B. S. Shop.		Carpenter-shop.		Machine-Drills.		Explosives.	
1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo	6 Mos.	1 Mo.	6 Mos	1 Mo.	6 Mos.	1 Mo.	6 Mos.
					1,214.68			3,648.71	20,728.88	3,135.00	18,307.30
149.22	9,427.37										
		24.30	280.03	16.91	106.66	96.91	584.25				1.37
		66.29	505.63	7.26	39.64						
					2.28	4.55	4.55				
						10.90	16.40				
						6.80	86.80				
		27.00	27.00			5.95	87.70				
											1.18
149.22	9,427.37	117.59	812.66	24.17	1,413.26	125.11	779.70	3,648.71	20,728.88	3,135.00	18,309.80

	1,156.52				541.42			620.42	5,385.18	846.48	7,950.04
								845.37	3,613.45	984.58	4,804.73
	617.89							151.70	1,745.84	142.18	1,838.61
					101.98		55.50		962.40		457.23
	495.04	229.77	229.77	21.33	21.33	17.00	21.66	23.16	23.16	16.31	48.58
			55.13	4.53	196.39	98.40	350.66	277.93	1,353.83	248.15	1,564.80
						114.88	1,615.72				
		16.06	410.18		7.53	718.70	2,960.82				
		2,034.40	6,010.71	166.08	840.83	57.90	741.17				
	2,269.45	2,280.23	6,705.79	191.94	1,209.48	1,006.88	5,745.53	1,918.58	13,027.86	2,237.70	16,163.49
149.22	11,696.82	2,397.82	7,518.45	216.11	2,622.74	1,131.99	6,525.23	5,567.29	33,756.34	5,372.70	34,473.29

Accounts.

		99.36		42.89		2.30					
		22.54									
		34.97		16.95		19.75					
		208.85									
		125.55		40.19							
				12.08							
				1.94							
		65.88									
		7.88									
		203.58		1,728.13							
						547.43					
		251.77									
				2.94							
		1,020.38		1,845.12		569.48					
149.22		3,418.20		2,061.23		1,701.47		5,567.29		5,372.70	

their names and credited in the vertical columns below their names.
the operating costs, but their amounts are distributed or charged
of "Stoping," "Plant and Development" and "Milling."

Form 1.—*Portland Gold Mining Company.*—

Lumber and Timber.		Supplies.		Surface Expense.		Fuel.		C. S. Office.		Pay-Roll.	
1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.
....	....	43.11	570.19	....	....	....	....	....	....	10,023.74	60,459.22
....	....	....	80.00	....	....	....	....	....	....	4,723.75	30,377.82
4,690.45	11,097.18	....	39.36	....	....	....	....	....	....	4,270.50	21,391.26
....	....	....	....	....	....	....	....	....	....	....	....
5.36	30.76	129.47	676.01	145.88	313.11	....	....	....	....	5,893.23	35,469.89
....	21.02	35.13	1,864.06	....	....	....	....	....	....	291.00	5,220.64
0.80	0.80	370.95	1,706.10	....	....	....	....	....	....	....	....
....	2.20	4.06	16.63	....	....	....	....	....	....	....	373.88
....	3.12	59.52	100.54	....	2.33	....	....	....	....	96.38	547.51
18.80	117.60	6.55	43.37	185.87	1,287.52	....	....	....	....	....	....
....	....	8.38	27.53	99.12	187.71	....	....	....	1,214.14	186.00	1,091.00
....	....	....	....	....	....	....	....	3,028.51	22,099.98	....	....
....	....	....	....	....	....	....	....	....	15,261.49	....	....
....	....	....	....	....	....	....	....	3,290.00	6,974.89	....	....
....	....	....	....	....	....	....	....	....	....	....	....
4,715.41	11,272.68	657.17	5,123.79	430.87	1,790.67	....	....	6,318.51	45,550.50	25,484.90	154,931.22
35.85	35.85	....	94.97	....	....	....	....	....	....	2,147.18	18,556.99
....	....	....	....	....	....	....	....	....	....	3,089.03	13,230.85
99.82	249.10	....	....	....	....	....	....	....	....	808.13	7,747.56
10.28	563.41	....	184.87	....	....	....	....	....	....	48.00	3,235.49
5.16	41.88	18.32	53.72	....	....	....	....	....	....	131.81	223.81
407.30	2,025.79	82.06	590.51	....	....	....	162.00	....	....	1,987.10	10,431.78
185.60	2,264.54	....	72.50	....	130.64	....	....	....	....	....	....
881.82	2,918.27	1,545.33	2,122.99	....	270.85	....	....	....	....	....	96.00
66.60	843.62	2,278.20	6,204.65	14.50	330.49	....	....	....	8,038.97	....	51.25
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
1,692.43	8,942.46	3,873.91	9,324.21	14.50	731.98	....	162.00	....	8,038.97	8,211.25	53,573.73
6,407.84	20,215.14	4,531.08	14,448.00	445.37	2,522.65	....	162.00	6,318.51	33,589.47	33,696.15	208,504.95
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....

Distributed

....	....	464 92	....	....	....	5,063.10	....	....	....	1,073.25	....
....	....	130.66	....	....	....	....	....	....	....	279.00	....
....	....	363.08	....	....	....	....	....	....	....	2,886.44	....
....	....	177.78	....	....	....	....	....	....	....	....	....
8.16	....	182.17	....	212.50	....	....	....	....	....	81.00	....
....	....	187.14	....	....	....	....	....	....	....	....	....
1.20	....	92.92	....	....	....	....	....	....	....	3,168.64	....
....	....	92.92	....	....	....	....	....	....	....	1,660.69	....
....	....	13.30	....	....	....	....	....	....	....	1,657.39	....
....	....	599.88	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	192.75	....
....	....	....	....	320.89	....	....	....	....	....	....	....
....	....	....	....	75.12	....	....	....	....	....	70.00	....
....	....	11.18	....	....	....	....	....	....	....	990.76	....
....	....	....	....	....	....	....	....	....	....	....	....
9.36	....	2,265.95	....	608.51	....	....	....	....	....	12,059 92	....
6,417.20	....	6,797.03	....	1,053.88	....	5,063.10	....	....	....	45,756.07	....

General Cost-Sheet.—Continued.

Gen. Office.		Total Debits.		Cost per Ton Crude.		Cost per Ton Shipped.		Cost per Ounce Gold.		
1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	1 Mo.	6 Mos.	
285.00	1,887.96	17,135.56	103,168.23	0.8390	0.84.79	2.1864	2.1651	1.7328	1.8101	Breaking ore.
140.00	636.67	5,382.67	33,947.42	0.2635	0.27.90	0.6868	0.7124	0.5443	0.5956	Tramming.
....	399.96	9,110.17	42,355.13	0.4460	0.34.81	1.1624	0.8889	0.9213	0.7431	Timbering.
....	100.00	4,118.60	26,056.40	0.2016	0.21.41	0.5255	0.5470	0.4165	0.4572	Hoisting.
191.50	1,276.50	6,864.50	40,598.44	0.3361	0.33.37	0.8759	0.8520	0.6942	0.7123	Sorting and loading.
....	100.00	1,640.99	27,318.77	0.0803	0.22.45	0.2094	0.5733	0.1659	0.4793	Pumping.
....	859.23	1,285.83	7,092.15	0.0630	0.05.83	0.1641	0.1488	0.1300	0.1244	Lighting.
615.77	4,390.75	624.38	4,790.29	0.0306	0.03.94	0.0797	0.1005	0.0631	0.0840	Assaying.
211.39	1,226.04	378.19	1,895.94	0.0185	0.01.56	0.0483	0.0398	0.0383	0.0333	Surveying.
....	108.80	218.02	1,644.09	0 0107	0.01.35	0.0278	0.0345	0.0220	0 0288	Repairs.
3,948.64	9,033.80	4,455.41	12,381.08	0.2181	0.10.18	0.5686	0.2598	0.4506	0.2172	General expense, Victor.
0.35	84.94	3,028.86	22,186.05	0.1483	0.18.23	0.3865	0.4656	0.3063	0.3892	General expense, Colo. Sp.
....	....	....	15,261.49	....	0.12.54	....	0.3203	....	0.2678	Insurance and taxes.
100.00	300.00	3,390.00	7,274.89	0.1660	0.05.98	0.4326	0.1527	0.3428	0.1277	Litigation.
....	....	6,114.05	24,812.50	0.2993	0.20.39	0.7801	0.5207	0.6183	0.4353	Development charged to stoping—2,571 tons.
5,492.65	20,404.65	63,747 23	370,782.87	3.1210	3.04.73	8.13.41	7.78.14	6.4464	6.50.53	Total.
....	283.59	4,058.68	37,298.14	....	....	0.5179	0.7828	0.4104	0.6544	Drifts.
....	121.07	5,568.45	23,709.47	....	....	0.7105	0.4976	0.5631	0.4158	Cross-cuts.
....	110.31	1,301.00	12,258.12	....	....	0.1660	0.2572	0.1315	0.2150	Raises.
....	45.50	62.00	5,904.65	....	....	0.0079	0.1239	0.0063	0.1035	Shaft No. 1.
....	....	480.34	1,176.43	....	....	0.0618	0.0247	0.0486	0.0205	Shaft No. 2.
... .	50.25	3,055.47	17,104.48	....	....	0.3900	0.3589	0 3089	0.3008	Shaft No. 3.
....	....	300.48	4,083.40	....	....	0.0382	0.0857	0.0304	0.0716	Cribbing.
962.54	4,386.96	4,124.45	13,173.60	....	....	0.5263	0.2765	0.4171	0.2310	Buildings.
2,686.73	33,652.88	7,304.41	56,204.57	....	....	0.9320	1.1795	0.7386	0.9861	Machinery.
....	....	26,255.28	170,912.86	....	....	3.3501	3.5868	2.6549	2.9987	Total.
....	....	6,114.05	24,812.50	....	....	0.7801	0.5207	0.6183	0.4353	Less dev. charged to stop'g.
3,649.27	38,650.56	20,141.23	146,100.36	....	....	2.5700	3.0661	2.0366	2.5634	Total.
9,141.92	59,055.21	83,888.46	516,883.23	....	....	10.7041	10.8475	8.4830	9.0687	Total cost mining.
....	....	34,506.48	284,868.31	....	....	7.0860	7.4695	....	....	Portland mill (oper'n).
....	....	35,856.94	111,670.72	....	....	12.0831	11.7405	....	....	Other freight—treat.,.
....	....	70,363.42	396,539.03	....	....	8.9781	8.3219	7.1153	6.9573	
....	....	154,251 88	913,922.26	....	....	19.6822	19.1694	15.5983	16.0260	

Accounts.

7.75	....	6,753.57	....	....	....	....	....	....	....	**Boiler-room.**
....	....	2,993.83	....	....	....	....	....	....	....	**Compressing.**
5.00	....	5,166.54	....	....	....	....	....	....	....	**Hoisting, 21,836 tons.**
....	....	914.08	....	....	....	....	....	....	....	**Electric plant.**
....	....	649.57	....	....	....	....	....	....	....	**Tramming, 22,349 tons.**
....	....	149.22	....	....	....	....	....	....	....	**Timbering.**
153.50	....	3,418.20	....	....	....	....	....	....	....	**Machine-shop.**
241.74	....	2,061.23	....	....	....	....	....	....	....	**Blacksmith-shop.**
22.90	....	1,701.47	....	....	....	....	....	....	....	**Carpenter-shop.**
....	....	5,567 29	....	....	....	....	....	....	....	**Mach.-drills, 2,403¾ shifts.**
5,252.63	....	5,445.38	....	....	....	....	....	....	....	**Explosives.**
3,542.96	....	4,411.28	....	....	....	....	....	....	....	**Lumber and timber.**
3,735.81	....	4,132.70	....	....	....	....	....	....	....	**Supplies.**
49.00	....	1,053.88	....	....	....	....	....	....	....	**Surface expense.**
5,063.10	....	5,063.10	....	....	....	....	....	....	....	**Fuel.**
18,074.39	....	49,481.34	....	....	....	....	....	....	....	**General office.**
27,216.31	....	....	....	....	....	....	....	....	....	

Form 2.—*The Portland Gold Mining Co.—General Cost-Sheet.*

Ore Stoped, Month of.........190..., ...Tons. Ore Shipped, Month of.........190..., ...Tons. Fine Gold, Month of.........190..., ...Ounces. Development, Month of.........190..., ...Feet.
Ore Stoped, ...Months, ...Tons. Ore Shipped, ...Month, ...Tons. Fine Gold, ...Months, ...Ounces. Development, ...Months, ...Feet.

		Boiler-Room.		Com-press'g.		Mach'e-Drills.		Hoist-ing.		Auxil-iary Hoists.		Electric Plant.		Tram-ming.		Timber-ing.		Ore-Houses.		Waste Haul'ge System.		Surface Ex-pense.		Carpen-ter-Shop.		Black-smith-Shop.		Mach'e-Shop.		Fuel.	
		1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.
Operating Accounts. Stoping.	Breaking ore																														
	Tramming																														
	Timbering																														
	Hoisting																														
	Sorting and loading																														
	Pumping																														
	Lighting																														
	Assaying and sampling																														
	Surveying																														
	Repairs																														
	General expense—Victor																														
	General expense—C. S.																														
	Insurance and Taxes																														
	Litigation																														
	Total stoping																														
Development.	Drifts																														
	Cross-cuts																														
	Raises and winzes																														
	Shaft No. 1																														
	No. 2																														
	No. 3																														
	Lowell																														
	Total development																														
	Total cost mining																														
Mill'g.	Portland mill																														
	Other freight and treatment																														
	Total freight and treatment																														
	Total mining and milling																														
Perm. Equip.	Buildings																														
	Machinery																														
	Cribbing																														
	Head works																														
	Rolling stock and rail																														
	Pipe lines																														
	Tools and appliances																														
	Total plant account																														
	Total operating cost																														

NOTE.—Form 2, the original size of which is 21 x 43.5 in., covers 4 pages of this paper. The left half of the sheet is given on this and the opposite page, and the right half on the two following pages.—R. W. R.

DISTRIBUTED ACCOUNTS.

Boiler-room: Operation
Repairs and maintenance
Water-supply
Compressing: Operation
Repairs and maintenance
Air-lines
Machine-drills:
Repairs
Sharpening steel
New steel
Drill sharpener
Hoisting:
Repairs and maintenance
Top trammers
Shaft repairs and maintenance
Auxiliary hoists: Operation
Repairs and maintenance
Electric Plant: Dyn. & Engine
Repairs and maintenance
Lamps
Lines
Tramming: Apportioned
Timbering: Apportioned
Ore-houses: Rep. and main'ce
Sorting
Loading
Tramming waste
Washers—Operation
Washers—Rep. and maint'ce
Waste haulage system:
Rope haulage—Operation
Rep. & main.
L. B. Elevator—Operation
Rep. & main.
Belt conveyors—Operation
Rep. & main.
Surface expense
Carpenter-shop
Blacksmith-shop
Machine-shop
Fuel
Lumber and timber
Explosives
Supplies
Total distributed accounts
Totals
Invoice
Balance

EXPLANATION.—All accounts are debited in the horizontal columns opposite their names and credited in the vertical columns under their names.
The "Distributed Accounts" do not figure by themselves in the operating costs, but their amounts are distributed or charged out among the various Operating Accounts under the heads of "Stoping," "Development," "Milling" and "Permanent Equipment." The columns headed "Shaft 1, 2, 3 and Lowell" show subdivision of total costs by shafts.

FORM 2.—*The Portland Gold Mining Co.—General Cost-Sheet.—Continued.*

	Feet.		Lumber, Timber.		Explosives.		Supplies.		Pay-Roll.		General Office.		Shaft No. 1.		Shaft No. 2.		Shaft No. 3.		Lowell Shaft.		Total Debits.		Cost per Ton Crude.		Cost per Ton Shipp'd.		Cost per Ounce Gold.		Tons.	
	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.	1 Mo.	... Mos.
Breaking ore																														
Tramming																														
Timbering																														
Hoisting																														
Sorting and loading																														
Pumping																														
Lighting																														
Assaying and sampling																														
Surveying																														
Repairs																														
General expense—Victor																														
General expense—C. S.																														
Insurance and taxes																														
Litigation																														
Total stoping																														
Drifts																														
Cross-cuts																														
Raises and winzes																														
Shaft No. 1																														
No. 2																														
No. 3																														
Lowell																														
Total developm't.																														
Total cost mining																														
Portland mill																														
Other freight and treatment																														
Total freight and treatment																														
Total mining and milling																														
Buildings																														
Machinery																														
Cribbing																														
Head works																														
Rolling stock and rail																														
Pipe lines																														
Tools and appliances																														
Total plant account																														
Total operating cost																														
Net																														
Gross																														

DISTRIBUTED ACCOUNTS.

Boiler-room : Operation																										
Repairs and maintenance																										
Water-supply																										
Compressing : Operation																										
Repairs and maintenance																										
Air-lines																										
Machine-drills :																										
Repairs																										
Sharpening steel																										
New steel																										
Drill sharpener																										
Hoisting :																										
Repairs and maintenance																										
Top trammers																										
Shaft repairs and maintenance																										
Auxiliary hoists : Operation																										
Repairs and maintenance																										
Electric plant : Dyn'o and engine																										
Repairs and maintenance																										
Lamps																										
Lines																										
Tramming : Apportioned																										
Timbering : Apportioned																										
Ore-houses : Repairs and main'nce																										
Sorting																										
Loading																										
Tramming waste																										
Washers—Operation																										
Washers—Repairs and main'nce																										
Waste haulage system :																										
Rope haulage —Operation																										
Repairs and maintenance																										
L. B. elevator—Operation																										
Repairs and maintenance																										
Belt conveyors—Operation																										
Repairs and maintenance																										
Surface expense																										
Carpenter-shop																										
Blacksmith-shop																										
Machine-shop																										
Fuel																										
Lumber and timber																										
Explosives																										
Supplies																										
Total distributed accounts																										
Totals																										
Invoice																										
Balance																										

FORM 3.—*Portland Gold Mining Co.*—

For month ending

		Machine-Men.	Hand-Miners.	Shovelers.	Trammers.	Pipe- and Track-men.	Timbermen.	Timber Helpers.	Total Labor.	Machines (Large or Small).	Number Machine Shifts Worked.
200	Portland	40.00			27.00	3.00	14.00	12.00	96.00	S.	10
400	Bobtail	142.00		3.00	81.00	4.13	42.00	36.00	308.13		35½
	No. 4 Lee			66.00	54.00	2.25	14.00	12.00	148.25		
	No. 5 Captain	453.50	154.50	739.13	547.88	28.13	361.82	420.00	2,704.96		113¾
	No. 7 Captain	588.00	6.00	12.00	145.50	10.13	128.62	111.76	1,002.01		147
	No. 9 Captain	648.00	4.13	30.58	66.50	16.50	106.32	91.13	963.16		162
500	No. 3 Captain	164.00	1.13	165.38	134.25	24.38	357.00	325.88	1,172.02		41
	No. 4 Captain	320.00		12.38	104.35	1.50	47.25	49.50	534.98		80
	No. 5 Captain	252.00	3.00	60.00	111.38	3.75	25.38	23.25	478.76		63
	No. 7 Captain	64.00		84.00	90.75	3.38	10.50	9.00	261.63		16
	No. 9 Captain	392.00		70.13	186.75	2.25	40.25	27.00	718.38		98
600	Burns	40.00		15.75	55.50		14.00	12.00	137.25		10
	Old No. 2		69.00		69.00	0.75	3.50	3.00	145.25		
	No. 2 Stope	236.00		109.50	132.00	4.50	59.50	51.00	592.50		59
	North Diamond					0.38	3.50	3.00	6.88		
	Bobtail	316.00		4.50	113.25	9.38	56.00	54.00	553.13		79
	No. 3 Captain	212.00	1.13	18.38	135.00	8.25	17.50	15.00	407.26		53
	No. 4 Captain	32.00			74.25				106.25		8
	No. 7 Captain	420.00		18.00	124.50		63.00	51.00	676.50		105
	No. 8 Captain	12.00			25.00	2.25			39.25		3
	No. 2 Hidden Treas.			15.00	28.50		3.50	3.00	50.00		
700	No. 2 Stope	384.00	118.50	178.50	198.00	4.13	87.50	51.00	1,021.63		96
	Rose						45.50	57.00	102.50		
	No. 1 Hidden Treas.		105.00	84.00	139.50	1.88	154.00	21.00	505.38		
	No. 2 Hidden Treas.			3.00	3.00		17.50	21.00	44.50		
	No. 3 Lee				6.00	1.13			7.13		
	No. 4 Lee	4.00		39.00	48.00	0.75			91.75		1
800	Bobtail				48.38	0.38			48.76		
	No. 1 Hidden Treas.			39.00	64.75	3.75			107.50		
	No. 3 Hidden Treas.			3.75	10.13	3.38			17.26		
900	No. 3 Hidden Treas.	624.00	82.50	109.50	345.00	5.63	136.50	138.00	1,441.13		156
	No. 4 Lee	202.00	3.00	30.00	81.00	6.38	35.00	30.00	387.38		50½
	East Fork	396.00			84.00	1.50			481.50		99
1,000	No. 3 Hidden Treas.	160.00	174.38	270.00	552.75	4.13	192.50	181.50	1,535.26		40
	No. 4 Lee	200.00		31.50	69.75	4.88	77.00	66.00	449.13		50
1,100	East Fork				9.00		7.00	6.00	22.00		
		6,301.50	722.27	2,211.98	3,965.62	162.83	2,120.14	1,881.02	17,365.36		1,575¾

Stope Report (Size of Original Sheet, 18 by 19.25 in.).

December 31, 1902.

Cost for Machines.	General Tramming Cost.	Explosives.	Lumber and Timber.	Hoisting.	Supplies.	General Expense: Bosses, Assaying, Surveying, etc.	Total Cost.	Tons Ore.	Tons Waste Hoisted.	Tons Waste Dumped in Old Stopes.	Total Tons.	Cost per Ton.
23.16	2.44	32.04	....	19.87	3.09	37.90	214.50	56	28	....	84	2.55
82.22	7.55	82.83	37.26	61.28	9.58	117.18	706.03	225	34	....	259	2.72
....	8.42	4.45	....	68.62	10.68	130.76	371.18	266	24	....	290	1.29
262.58	60.37	3.06	1,475.90	491.20	76.53	936.77	6,110.24	1,918	158	....	2,076	2.94
		98.87										
340.47	31.72	193.61	38.16	258.13	40.19	492.08	2,396.37	1,080	11	....	1,091	2.20
375.21	30.78	345.20	36.30	250.35	39.01	477.55	2.517.56	1,055	3	....	1,058	2.38
94.96	21.59	57.19	1,003.96	117.40	27.33	334.79	2,829.24	389	107	246	742	3.81
185.29	11.05	246.12	19.56	82.57	13.99	171.50	1,265.06	343	6	31	380	3.33
145.92	17.65	104.01	16.10	133.92	22.37	273.83	1,192.56	500	66	41	607	1.96
37.06	13.55	27.61	13.60	103.63	17.18	210.35	684.61	323	115	28	466	1.47
226.98	20.39	216.02	16.40	159.24	25.83	316.15	1,699.39	639	34	28	701	2.42
23.16	5.23	15.23	7.64	42.58	6.62	81.17	318.88	170	10	....	180	1.77
....	6.04	19.86	....	49.21	7.46	93.80	321.62	176	32	....	208	1.54
136.65	19.14	154.87	68.59	155.69	24.25	296.88	1,448.57	613	45	....	658	2.20
....	....	1.45	....	....	....	....	8.33	....	....	....	....	....
182.97	11.43	132.97	39.15	92.99	14.50	177.50	1,204.64	386	7	....	393	3.06
122.75	12.57	119.97	23.00	102.45	15.93	195.19	999.12	389	44	....	433	2.31
18.53	7.10	17.08	3.25	57.73	8.99	110.23	329.16	181	63	....	244	1.35
243.18	13.65	216.87	26.58	113.35	17.30	211.83	1,519.26	412	67	....	479	3.17
6.95	1.81	39.71	....	14.67	2.29	28.11	132.79	49	13	....	62	2.14
....	2.44	....	....	19.87	3.09	37.90	113.30	66	18	....	84	1.35
222.35	31.20	179.39	411.90	241.10	39.51	484.18	2,631.26	970	49	54	1,073	2.45
....	....	....	177.33	....	....	....	279.83	....	....	....	....	....
....	18.03	12.55	107.20	146.67	22.83	279.51	1,092.17	494	126	....	620	1.76
....	1.08	9.43	39.70	8.75	1.35	16.74	121.55	15	22	....	37	3.29
....	2.14	2.12	....	17.51	2.70	33.16	64.76	67	7	....	74	0.88
2.32	4.68	14.06	....	38.09	5.92	72.64	229.46	148	13	....	161	1.42
....	4.92	0.88	....	40.22	6.24	76.43	177.45	143	27	....	170	1.04
....	5.03	....	....	40.93	6.37	78.01	237.84	138	35	....	173	1.37
....	3.32	0.61	....	26.97	4.17	51.48	103.81	101	13	....	114	0.91
361.30	41.27	325.90	240.10	335.74	52.25	640.20	3,437.89	1,195	224	....	1,419	2.42
116.96	15.77	89.80	63.42	128.23	19.96	244.46	1,065.98	513	29	....	542	1.97
229.29	12.86	171.92	....	100.08	16.29	199.61	1,211.55	422	1	19	442	2.74
92.64	58.79	105.22	760.50	478.41	74.53	912.14	4,017.49	1,640	382	....	2,022	1.98
115.81	14.36	94.10	63.55	116.65	18.16	222.66	1,094.42	461	32	....	493	2.22
....	0.55	....	1.30	4.50	0.68	8.53	37.56	19	....	....	19	1.97
3,648.71	518.92	3,135.00	4,690.45	4,118.60	657.17	8,051.22	42,185.43	15,562	1,845	447	17,854	2.36

FORM 4.—*The Portland Gold Mining Company*

For Month Ending

	Drifts.	Machine-Men.	Machine Helpers.	Hand-Miners.	Shovelers.	Trammers.	Pipe- and Track-men.	Timbermen.	Timber Helpers.	Total Labor.
200	Burns....S.	56.00	....	3.00	....	54.00	22.50	24.50	21.00	181.00
400	Tidal Wave....S.	80.00	....	....	....	42.00	10.94	0.44	....	133.38
500	Bobtail....N.	196.00	....	....	....	50.00	12.38	....	....	358.38
....	No. 5 Captain....S.	36.00	....	....	....	121.75	2.63	....	....	60.38
600	Burns....SW.	40.00	....	....	....	22.50	4.13	....	....	66.63
....	No. 8 Captain....S.	8.00	....	....	....	3.75	0.75	....	....	12.50
800	No. 2 Captain....S.	112.00	....	....	....	83.25	10.88	....	....	206.13
....	No. 3 Captain....N.	....	....	....	....	1.50	0.75	....	....	2.25
....	No. 3 Captain....S.	51.00	....	....	....	44.25	1.88	....	....	97.13
....	No. 4 Captain....N.	....	....	....	....	....	0.38	....	....	0.38
900	No. 4 Captain....N.	80.00	....	....	....	43.88	2.25	....	....	126.13
....	No. 4 Captain....S.	80.00	....	....	....	41.25	5.63	....	....	126.88
1,000	No. 4 Captain....N.	40.00	....	....	....	15.75	25.50	....	....	81.25
....	No. 3 Hidden Treasure...N.	108.50	24.50	27.00	....	342.50	14.25	....	....	516.75
1,100	No. 3 Hidden Treasure....N.	52.00	....	....	....	27.38	4.25	....	....	83.63
....	No. 3 Hidden Treasure....S.	52.00	....	....	....	39.00	3.38	....	....	94.38
....	....	991.50	24.50	30.00	....	932.76	122.48	24.94	21.00	2,147.18
	Cross-cuts.									
Adit	No. 4 Captain....W.	44.00	....	....	....	32.62	2.63	....	....	79.25
....	No. 4 Captain....E.	56.00	....	....	....	37.87	4.50	....	....	98.37
500	No. 7 Captain....NE.	212.00	....	....	....	181.88	16.13	....	....	410.01
600	Burns....E.	44.00	....	....	....	27.00	2.25	....	....	73.25
....	No. 8 Captain....E.	436.00	....	....	365.25	338.63	20.25	....	....	1,160.13
700	No. 2 Hidden Treasure...E.	176.00	....	....	....	133.50	12.00	....	....	321.50
1,100	From No. 1 Shaft....S.	....	....	18.00	....	9.00	3.00	....	....	30.00
....	No. 1 Shaft to No. 2....N.	50.00	45.50	....	....	63.00	6.38	Contract. 267.50	....	432.38
....	No. 2 Shaft to No. 1....S.	64.00	49.00	....	....	42.00	1.13	245.00	....	401.13
....	No. 1 Cross-cut from No. 2 D....W.	56.00	....	....	....	23.63	3.38	....	....	83.01
....	....	1,138.00	94.50	18.00	365.25	889.13	71.65	512.50	....	3,089.03
	Raises.									
400	No. 1 Tidal Wave....	96.00	33.25	168.00	....	45.38	4.50	122.50	51.00	520.63
....	No. 2 Tidal Wave....	128.00	....	....	....	70.50	4.50	45.50	39.00	287.50
....	....	224.00	33.25	168.00	....	115.88	9.00	168.00	90.00	808.13
	Shaft.								Contract.	
600	No. 2 Station....	40.00	....	....	....	3.00	21.00	1.31	39.50	131.81
1,100	Burns' Station....	....	....	....	....	6.00	....	....	42.00	48.00
....	No. 3 Shaft....	....	....	....	....	....	....	42.50	1,725.60	1,768.10
....	....	40.00	....	....	....	9.00	21.00	43.81	1,807.10	1,947.91

Development Report (Size of Original Sheet, 18 by 19.25 in.).

December 31, 1902.

Machines (Large or Small).	Number Machine Shifts Worked.	Cost for Machines.	General Tramming Cost.	Explosives.	Lumber and Timber.	Hoisting.	Supplies.	General Expense: Bosses, Assaying, Surveying, etc.	Total Cost.	Tons Ore.	Tons Waste Hoisted.	Tons Waste Dumped in Old Stopes.	Total Tons.	No. Feet.	Cost per Foot.
S.	14	32.43	3.76	42.80	35.85	80.53	....	58.43	384.30	3	126	....	129	26½	14.50
......	20	46.32	3.01	74.26	....	24.62	....	46.74	328.33	......	104	....	104	83	9.95
......	49	113.49	10.70	189.67	....	87.10	....	166.12	925.46	174	194	....	368	92	10.06
......	9	20.84	1.12	32.50	....	4.73	....	17.37	136.94	16	4	19	39	15	9.13
......	10	23.16	0.98	21.15	....	8.05	....	15.16	135.13	5	29	....	34	18	7.56
......	2	4.63	0.55	5.99	....	4.50	....	8.53	36.70	11	8	....	19	....	....
......	28	64.85	4.82	70.30	....	39.29	....	74.85	460.24	116	50	....	166	29½	15.60
......	....	....	0.20	....	....	1.66	....	3.16	7.27	6	1	....	7	....	....
......	12¾	29.58	2.42	48.25	....	19.65	....	37.59	234.57	48	35	....	83	34	6.89
......	....	....	....	....	....	....	....	....	0.38	......	......	....	....	....	....
......	20	46.32	2.30	38.85	....	18.70	....	35.69	267.99	15	64	....	79	31	8.64
......	20	46.32	3.68	72.76	....	30.06	....	57.17	336.87	106	21	....	127	37	9.10
......	10	23.16	1.20	33.98	....	9.70	....	18.64	167.93	......	41	....	41	16	10.49
L.	7	32.43	5.61	110.93	....	45.67	....	87.17	875.28	3	190	....	193	61½	14.28
S.	20⅛	76.72													
	13														
......	13	30.11	2.16	52.77	....	17.51	....	33.48	219.66	......	74	....	74	25	8.78
......	13	30.11	2.69	52.77	....	21.77	....	41.69	243.41	41	51	....	92	29	8.39
......	260⅞	620.42	45.20	846.48	35.85	363.54	....	701.79	4,760.46	544	992	19	1,555	447½	10.63
......	11	25.48	1.91	61.51	....	15.62	....	29.68	213.45	......	66	....	66	29½	7.23
......	14	32.42	2.79	57.06	....	22.72	....	43.27	256.63	......	96	....	96	31½	8.14
......	53	122.74	11.34	225.14	....	81.17	....	175.92	1,026.32	......	343	47	390	107½	9.55
......	11	25.48	1.44	50.38	....	11.83	....	22.42	184.80	......	50	....	50	27	6.85
......	109	252.44	40.82	177.10	....	328.34	....	625.99	2,584.32	1,074	313	....	1,387	14	184.59
......	44	101.92	7.69	165.83	....	62.39	....	119.39	778.72	5	259	....	264	94	8.28
......	....	....	1.04	2.47	....	8.52	....	16.11	58.14	......	36	....	36	....	....
L.	13	60.22	1.77	82.48	....	14.43	....	27.48	676.66	......	61	....	61	53½	12.65
L.	12½	57.90													
S.	2	4.63	2.22	108.06	....	17.98	....	34.48	698.15	......	76	....	76	49	14.24
L.	14	64.85													
L.	14	64.85													
S.	14	32.43	1.75	54.55	....	14.20	....	27.16	213.10	......	60	....	60	21½	9.91
......	311½	845.36	72.27	984.58	....	577.20	....	1,121.85	6,690.29	1,079	1,360	47	2,486	427½	15.65
S.	14½	33.58													
L.	9½	44.00	5.93	77.00	67.69	48.32	....	92.01	889.16	49	155	....	204	72	12.35
......	32	74.12	4.92	65.14	32.13	40.00	....	76.44	580.25	1	168	....	169	48	12.09
......	56	151.70	10.85	142.14	99.82	88.32	....	168.45	1,469.41	50	323	....	373	120	12.24
S.	10	23.16	1.91	16.31	....	3.31	18.32	29.69	224.51	......	66	....	66	....	....
......	....	....	0.41	....	....	15.57	....	6.32	70.30	......	14	....	14	....	....
L.	60	277.93	....	248.15	....	....	32.06	....	2,326.24	......	944	....	944	94½	24.72
......	70	301.09	2.32	264.46	....	18.88	50.38	36.01	2,621.05	......	1,024	....	1,024	94½	2 24.7

FORM 5.—*The Portland Gold Mining Co.—Shift Report.**

Victor, Colo., ...190...

Shaft No........ ....M. Shift.

Shifts.	@		
		Shift-boss.	In stopes.
		Machine-men.	
		Miners.	
		Muckers.	
		Stope sweepers.	
		Trammers.	
		Timbermen.	
		Timber helpers.	
		Nippers.	General.
		Track- and pipe-men.	
		Cagers.	
		Topmen.	
		Car greasers.	
		Powdermen.	
		Machine-men.	Development.
		Miners.	
		Trammers.	
		Timbermen.	
		Timber helpers.	
		Total Shifts.	

....

Shift-Boss.

* Size of original sheet, 8.5 by 5.5 in.

FORM 6.—*The Portland Gold Mining Co.—Ore-House Report.**

Portland, Colo., ...190...

No. 1.		Occupation.	No. 2.	
Shifts.	@		@	Shifts.
		Ore-house boss.............		
		Sorters........................		
		Trammers......................		
		Loaders.........................		
		Loaders.........................		
		Screen-men....................		
		Samplers.......................		
		Men on washers.....		
		Men on elevator............		
		Totals........................		
		Cars waste to dump.........		
		Cars loaded....................		

....

Ore-House Foreman.

* Size of original sheet, 8.5 by 5.5 in.

FORM. 7.—*The Portland Gold Mining Co.—Surface Report.**

Portland, Colo., ...190...

Shifts.	@	
		Men on dump-tracks.
		Men on cribbing..
		Men unloading lumber.
		Men unloading lagging and stulls.
		Men unloading cribbing timbers.
		Men unloading coal.
		Men unloading ....
		Teamster and team....................................
		Painter..
		Watchmen.
		Men..
		Men..
		Men..

....

Surface Foreman.

* Size of original sheet. 8.5 by 5.5 in.

FORM 8.—*The Portland Gold Mining Co.—Carpenter-Shop Report.**

Portland, Colo., ...190...

Shifts.	@	Occupation.
		Carpenters in shop....................................
		Sawyers in shop.......................................
		Sawyer helpers in shop................................
		Carpenters on...
		Carpenters on...
		Carpenters on...
		Carpenters on...
		Carpenters on...
		Carpenters on...
		Men cutting lagging...................................
		Men on cribbing at....................................
		Men on cribbing at....................................
		....
		Foreman...
		Total...

....

Carpenter Foreman.

* Size of original sheet, 8.5 by 5.5 in.

FORM 9.—*The Portland Gold Mining Co.—Distribution of Labor in Machinery Department* (Size of Original Sheet, 11 by 6 in.).

	No. 1 Shaft.	No. 2 Shaft.	No. 3 Shaft.	Total.
Machinery, Repairs and Construction. No...				
On air-drill repairs........................				
Machinists on repairs.........................				
Machinists on new work.................				
Machinists' helpers........................				
Boilermakers..............................				
Boilermakers' helpers.....................				
Pipe- and chain-gang.......................				
Electrician..................................				
Apprentice...................................				
Men on Engines and Compressors. No...				
Hoisting-engine, top.......................				
Hoisting-engine, underground..........				
Engine-wiper................................				
Compressor..................................				
Waste-haulage..............................				
Men on Boilers. No...				
Firemen......................................				
Boiler-cleaner..............................				
Pump-Men. No...				
Mine-pumps, station......................				
Mine-pumps, sinking......................				
Gulch-pump..................................				
Head pumpmen.............................				
Blacksmith-Shop. No...				
Blacksmiths.................................				
Blacksmiths' helpers......................				
Special Help. No...				
Haulage-system.............................				
Cables..				
Cleaning, sorting, etc....................				
....				
....				
....				
....				
....				
Total men....................................				

FORM 10.—*The Portland Gold Mining Co.—Blacksmith-Shop Report.**

Portland, Colo.,........................190...

Hours.	No.	
		Blacksmiths sharpening drills.
		Helpers sharpening drills.
		Blacksmiths repairing drills.
		Helpers repairing drills.
		Blacksmiths making new drills.
		Helpers making new drills.
		Blacksmiths on general work.
		Helpers on general work.
		Blacksmiths on..
		Helpers on..
		Blacksmiths on..
		Helpers on..
		Blacksmiths on..
		Helpers on..
		Blacksmiths on..
		Helpers on..

....

Blacksmith Foreman.

* Size of original sheet, 8.5 by 5.5 in.

FORM 11.—*The Portland Gold Mining Co.—Mechanical Department.**

	Hours.	Total.
No.............. Hoist..............................		
No.............. Compressor..............................		
No.............. Boiler-room..............................		
Dynamo-engine..............................		
Electric-lines..............................		
Waste-haulage..............................		
Air-drills..............................		
Air-lines..............................		
Steam-lines..............................		
Water-lines..............................		
Tram-cars..............................		
....		
....		
....		

Date..

Name..

* Size of original sheet, 5.5 by 4.5 in.

FORM 12.—*The Portland Gold Mining Co.—Order on Storekeeper.*

....190...

Storekeeper will please deliver to bearer and charge to..................................

....	....	....
....	....	....
....	....	....

(Size of original sheet, 4 by 6 in.)

....Foreman.

FORM 13.—*The Portland Gold Mining Co.—Ammunition Order.*

..................O'Clock Shift. ....190...

..................Level. Place Working ....

.....................Sticks 1¼" Powder.
.....................Sticks ⅞" "

(Size of original sheet, 3.5 by 6 in.)

....Lengths Fuse ....Feet Long.
.... " " .... " "
.... " " .... " "

....Machine Man.

In sending in above order, Machine-Men must fill out the blanks indicating the level and place working. Always sign your orders.

FORM 15.—*The Portland Gold Mining Co.—Timberman's Report.*

............O'Clock Shift..............Date.

............Level............Stope or Drift.

Posts,	
Caps,	
Sills,	
Ties,	
But caps,	(Size of original sheet, 6 by 4 in.)
Stulls,	
Lagging. New,	
Lagging. Raised,	
Sprags,	
Ladders,	
Planks, ft.,	

....

Timberman.

FORM 18.—*The Portland Gold Mining Co.—Trammer's Tag.**

.........O'Clock Shift,...................190...

Ore.	Mill Dirt.	Waste.
....	....	....

Trammed from..................................

Level No........ and Run to..............

....

Taken from

Chute.	Platt.	Rough Bottom.
....	....	....

To be delivered in bin No................

....

Trammer.

Trammers will indicate whether "Ore," "Mill Dirt" or "Waste," by putting an X underneath the word; the same with "Chute," "Platt" or "Rough Bottom." Fill in and date blanks, sign name and send out with car.

If on other work than tramming, state number of hours.

* Size of original sheet, 5.5 by 3.5 in.

FORM 14.—*Portland Gold Mining Co.—Powder-Man's Report.**

Day.	Level.			Level.			Level.			Level.			Level.			Level.			Level.		
	Name of Place.			Name of Place.			Name of Place.			Name of Place.			Name of Place.			Name of Place.			Name of Place.		
	Powder.	Fuse.	Caps.	Powder.	Fuse.	Caps.	Powder.	Fuse.	Caps.	Powder.	Fuse.	Caps.	Powder.	Fuse.	Caps.	Powder.	Fuse.	Caps.	Powder.	Fuse.	Caps.
1......																					
2......																					
3......																					
4......																					
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28......																					
29......																					
30......																					
31......																					

* Size of original sheet, 15 by 12 in.

FORM 16.—*The Portland Gold Mining Co.—Timber Report.**

Month of..........................190...

	Name of Place.										Name of Place.									
Day.	Posts.	Caps.	Sills.	Ties.	Butt Caps.	Stulls.	Lagging.	Planks—Ft.	Sprags.	Ladders.	Posts.	Caps.	Sills.	Ties.	Butt Caps.	Stulls.	Lagging.	Planks—Ft.	Sprags.	Ladders.
1......																				
2......																				
3......																				
4......																				
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24......																				
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26......																				
27......																				
28......																				
29......																				
30......																				
31......																				
Total..																				
Cost....																				

* Size of original sheet, 14 by 14 in.

FORM 17.—*The Portland Gold Mining Co.**

Shift-Bosses' Distribution-Sheet. **Month of........................190...**

Level .... **Place..**

	Shift.	Machine-Men.	Machine Helpers.	Hand-Miners.	Shovelers.	Trammers.	Pipe- and Track-Men.	Timber-Men.	Timber Helpers	Total Shifts.	Cars Ore Hoisted.	Cars Waste Hoisted.	Cars Waste Dumped in Stopes.	Total.
1	8													
	6													
2	8													
	6													
3	8													
	6													
4	8													
	6													
5	8													
	6													
6	8													
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	6													
27	8													
	6													
28	8													
	6													
29	8													
	6													
30	8													
	6													
31	8													
	6													
Total...														

Labor-cost......................			All other expense.........		
Explosives.....................			Total cost.....................		
Lumber and timber			Tons ore produced.........		
Machine-drills................			Per cent. shipped (est.)..		
Bosses, etc......................			Average assays..............		
Hoisting.........................			Estimated total value....		

* *Size of original sheet, 14 by 8 in.*

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Manufacture of Coke in Northern China.

BY YANG TSANG WOO, TONG SHAN, CHINA.

(Annual Meeting, February, 1905.)

THE method of making coke that has been adopted at the Kaiping and other collieries in northern China resembles, to some extent, the familiar bee-hive oven process of the United States, except that a kiln with permanent sides is used instead of a closed oven, and the products of combustion are drawn off at the bottom.

In building coke-kilns in China, two circular holes, 8 ft. 6 in. in diameter at the bottom and 13 ft. in diameter at the top, are excavated in the ground, both being connected at the bottom by a flue as shown in Fig. 1. The sides and bottom of the kiln are lined with fire-bricks, and covered with a layer of fire-clay, and a rectangular opening, 6 in. by 8 in., connects the bottom of each kiln with the main flue. Around the edge of the hole, and overlapping the lining, is a wall of fire-brick extending 2 ft. 6 in. above the level of the ground. An open space 5 ft. wide is left in this wall, through which the coal is carried into the kiln and the resultant coke removed. This space, of course, is bricked up during the time that the coking operation is being carried on. The wall is pierced with nine flue-openings uniformly placed around the circumference, each intervening space in the wall being strengthened with a brick buttress, as is shown in Figs. 2 and 4. The floor of the kiln, as well as the main flue, is lined with fire-brick.

Before charging the coal, it is first placed in shallow bamboo sieves, 2 ft. in diameter, and immersed in a trough 10 ft. long, and 3 ft. wide, fed with pit-water, in which it is washed by hand. Fig. 3 shows the manner in which the washing is done. From 25 tons of good "dust" coal, 22.5 tons of washed coal are obtained.

When ready to charge the coal into the kiln a temporary cone-shaped flue of fire-wood and lump coal is first built to a

height of 2 ft., directly above the rectangular opening in the bottom of the kiln; washed coal is then filled in to the level of the top of this flue, and stamped compactly in place by coolies wearing flat wooden-soled shoes. Then from the top of this flue nine temporary rectangular flues are made of broken fire-brick radiating from the center to the flue-openings in the wall. These flues have an interior cross-section 2 in. square at the center of the kiln, increasing to 7 in. square at the wall, and slope gradually upward toward the wall. On top of the stamped coal a flue 6 in. high is formed of coke, in order that air may reach the coal in the upper part of the kiln. The remainder of the charge of coal is then piled over the flues to a height of 6 ft., the top being rounded off as shown in Figs. 2 and 3.

After the fire has been started, and the operation of coking is well under way, any flame or gas escaping through the top of the coal in the kiln shows that the coal directly underneath the place of escape has been coked; and in order to prevent access of air, which would burn this coke, a layer of earth is spread over such places. After all the gases have escaped, water is poured on the top to extinguish the fire and to cool the coke. About two weeks are required for coking, and two days for cooling a charge. Each charge of 22.5 tons of washed coal yields 10 tons of good coke and 1 ton of ashes. The price of good "dust" coal at the pit-mouth is $4.50 (Mex.) per ton, and, as the coke sells at from $18 to $20 per ton, according to quality, the profit is considerable.

Analyses of coke made at the collieries of the Chinese Mining and Engineering Co., Tong Shan, North China, are:—carbon (by difference), 83,776; hydrocarbons, 0.060; sulphur, 0.969; moisture, 0.48; ash, 15.215; total, 100 per cent.

The washing of the coal, filling and discharging the ovens, and the coking-operations are done by contract which costs $6.50 (Mex.) per oven. Each contract-laborer earns about 20c. (Mex.) per day.

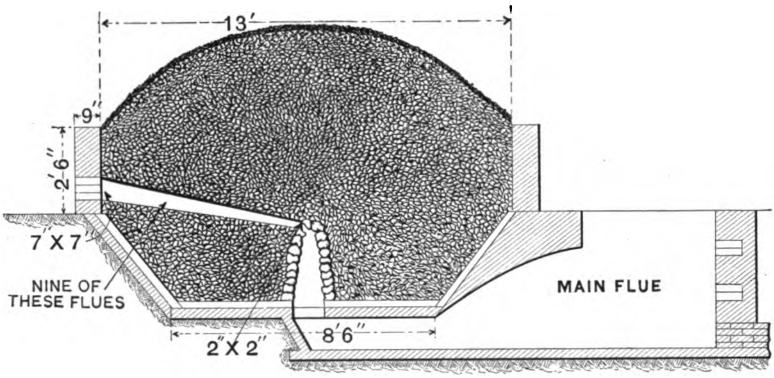

FIG. 1.—TRANSVERSE SECTION.

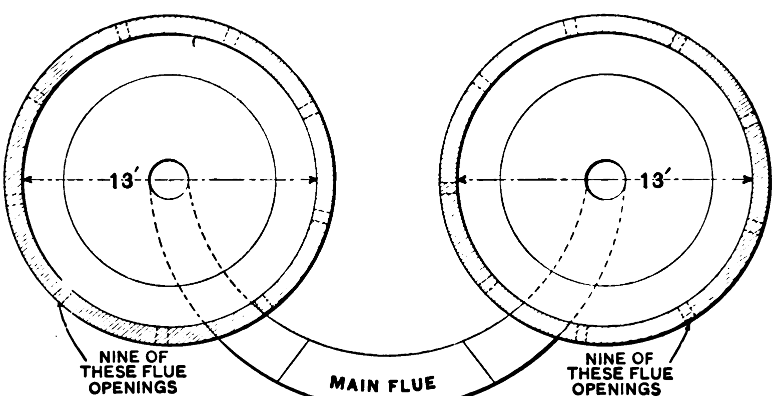

FIG. 2.—PLAN OF TWO ADJACENT KILNS.

COKE-KILNS AT KAIPING, CHINA.

FIG. 3.—Washing Coal in Troughs.

FIG. 4.—Charging Coal into Kilns.

COKE-KILNS AT KAIPING, CHINA.

Proceedings of the Eighty-Ninth Meeting, British Columbia, Canada, July, 1905.

COMMITTEES.

CENTRAL GENERAL COMMITTEE.—Wm. Fleet Robertson, *Chairman;* Wm. M. Brewer, *Secretary.*

LOCAL COMMITTEE OF NELSON, B. C.—A. S. Farwell, *Chairman;* W. C. Bayly, *Secretary;* William Blakemore, M. S. Davys, S. S. Fowler, R. R. Hedley, Leslie Hill, A. H. Kelly, W. C E. Koch, J. J. Campbell.

LOCAL COMMITTEE OF ROSSLAND, B. C.—His Worship Mayor Hamilton, *Chairman;* W. H. Aldridge, Charles Biesel, H. H. Claudet, F. .W. Guernsey, R. Marsh, J. W. Astley, R. W. Brock, A. A. Cole, A. G. Larsen, R. H. Stewart. Also the *Rossland Board of Trade,* Robert Hunter, *President;* K. E. Mackenzie, *Vice-President;* A. B. Mackenzie, *Secretary.*

LOCAL COMMITTEE OF GRAND FORKS, B. C.—His Worship Mayor Hammor, *Chairman;* A. W. B. Hodges, A. L. White, G. M. Fripp, L. A. Manley, W. T. Spier, G. W. Wooster.

LOCAL COMMITTEE OF VICTORIA, B. C.—Wm. Fleet Robertson, *Chairman;* William M. Brewer, *Secretary;* Harold Grant, Thomas Kiddie, Clermont Livingston, E. C. Musgrave, W. J. Sutton, Francis A. Thomson.

LOCAL COMMITTEE OF VANCOUVER, B. C.—C. F. Jackson, *Chairman;* His Worship Mayor F. Buscombe, J. J. Banfield, A. Bethune, John Boyd, H. C. Clarke, A. B. Erskine, E. P. Gilman, William Godfrey, W. D. Haywood, R. K. Houlgate, H. T. Lockyer, J. Y. McAdam, H. M. McDowell, C. W. McMeekin, W. H. Malkin, F. Richards, T. J. Smith, George A. Walkem, G. Sheldon Williams.

LOCAL COMMITTEE OF WHITE HORSE, Y. T.—Robert Lowe, *Chairman;* T. W. Jackson, *Secretary;* George Armstrong, A. L. Bindley, Rev. Father Corbeil, L. De Gex, A. E. Fisher, W. P. Grainger, P. D. McMillan, Rev. Mr. Main, George C. Mallot, Alfred Parre, George Pulham, George Reid, William Robinson, J. P. Scharschmidt, J. C. Schraeder, Major A. E. Snyder, Rev. Mr. Stringer, Judge George L. Taylor, William Taylor, H. Wheeler, E. J. White, J. P. Whitney.

LOCAL COMMITTEE OF DAWSON, Y. T.—Hon. W.W. B. McInnes, Commissioner of the Yukon Territory, *Honorary Chairman;* Major Z. T. Wood, Assistant Commissioner of the Yukon Territory, *Honorary Chairman;* J. B. Tyrrell, *Chairman;* J. Moore Elmer, *Vice-Chairman;* George Black, *Secretary;* Hon. Mr. Justice Dugas, Hon. Mr. Justice Macaulay, Hon. Mr. Justice Craig, Dr. Alfred Thompson, D. A. Cameron, E. W. Griffin.

The first session, held in the ministers' room of the Parliament Building, 3 p.m., Saturday, July 1st, was presided over by Past-President Robert W. Hunt. His Excellency the Lieut.-

Governor Sir Henri Joly de Lotbiniere was introduced by Mr. Wm. Fleet Robertson, Chairman of the Local Committee, and, in a few well-chosen remarks, extended a cordial welcome to the visiting members and guests of the Institute.

Hon. Richard McBride, Premier and Minister of Mines, was next introduced, and, reiterating the cordial sentiments of Sir Henri, gave a double welcome to the Institute. To these addresses Mr. Hunt responded.

The following papers were presented by their authors in oral abstract:

Geology and Mineral Resources of Vancouver Island, by W. J. Sutton, Victoria, B. C.

Smelting Copper-Ore Having a Large Percentage of Zinc, by Thomas Kiddie, Ladysmith, B. C.

Mechanical Charging of Copper Blast-Furnaces at Grand Forks, B. C., Canada, by A. B. W. Hodges, Grand Forks, B. C.

On Saturday evening a public reception was given in the Parliament Buildings.*

On Monday, July 3d, a steamer-excursion among the islands off the coast of Vancouver island was given by the Victoria Board of Trade.*

On Tuesday, July 4th, excursions were made to the mine of the Tyee Copper Co., at Mt. Sicker, and the smelting-works of the same company at Ladysmith.*

The second session was held at the same place, 10 a.m., Wednesday, July 5th, Past-President Robert W. Hunt presiding.

The following papers were presented in oral abstract by their authors:

The Geology of Deutschman's Cave near Glacier, Alta, by W. S. Ayres, Banff, Alberta, Can. (illustrated with lantern).

Geological Mine-Maps and Sections, by D. W. Brunton, Denver, Colo.

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* In addition to this formal record, a more particular account of all excursions and entertainments will be found in the general narrative prepared by the Secretary, and printed below.

The third and concluding session was held at 3 p.m. of the same day.

Mr. Wm. M. Brewer, of Victoria, gave an informal account of the mineral resources of the coast from Vancouver to Skagway, and a brief description of the geology of the country along the railroad from Skagway to White Horse and along the Yukon river from White Horse to Dawson.

The following papers were read by title:

Genetic Relations of the Western Nevada Ores, by J. E. Spurr, Washington, D. C.

The Gold-Placers of Seward Peninsula, Alaska, by Arthur J. Collier, Washington, D. C.

Reconnaissance Geology of the Northern Rockies, by R. H. Chapman, Washington, D. C.

The Formation of Ore-Deposits by Hot Springs, by Walter Harvey Weed, Washington, D. C.

Are the Quartz-Veins of Silver Peak, Nevada, the Result of Magmatic Segregation? by John B. Hastings, Denver, Colo.

The Electrolytic Assay of Lead and Copper, by George A. Guess, Silverton, Colo.

Tin Mining and Smelting at Santa Barbara, Mexico, by A. H. Bromly, Vancouver, B. C.

Anthracite Washeries, by George W. Harris, New York, N. Y.

The Importance of Fine Grinding in the Cyanide Treatment of Some Gold- and Silver-Ores, by Frederick C. Brown, Auckland, New Zealand.

Lead- and Zinc-Deposits of the Virginia-Tennessee Region, by Thomas Leonard Watson, Blacksburg, Va.

The Limestone-Granite Contact-Deposits of Washington Camp, Arizona, by W. O. Crosby, Boston, Mass.

Blast-Furnace Practice. A Discussion of the paper of James Gayley, "The Application of Dry-Air Blast to the Manufacture of Iron," and that of J. E. Johnson, Jr., "Notes on the Physical Action of the Blast-Furnace," by Charles B. Dudley, R. W. Raymond, J. E. Johnson, Jr., William F. Mattes, James Gayley, David Baker, John Birkinbine and F. E. Bachman.

Reply to Discussion by Arthur Jarman of the paper, "Equipment of a Laboratory for Metallurgical Chemistry in a Technical School," by Charles H. White, Cambridge, Mass.

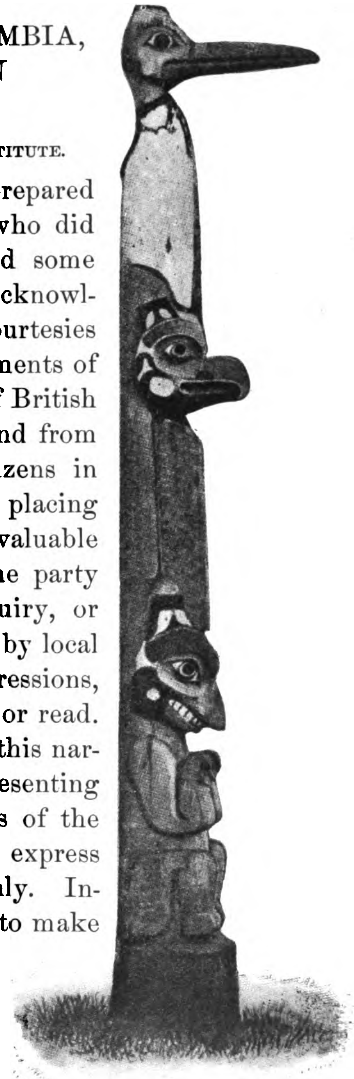
Discussion of the paper of H. O. Hofman, "The Effect of Silver on the Chlorination and Bromination of Gold," by T. K. Rose, London, England.

Discussion of the paper of James P. Roe, "The Manufacture and Characteristics of Wrought-Iron," by Messrs. Stafford, Cushman, Dudley, Hartshorne and Wittman.

On Wednesday evening, a social reception was given by Lieut.-Gen. Sir Henri Joly de Lotbiniere, at the Government House; and during the night, the members and guests of the Institute left Victoria for Vancouver.

EXCURSIONS IN BRITISH COLUMBIA, ALASKA AND THE YUKON TERRITORY.

BY R. W. RAYMOND, SECRETARY OF THE INSTITUTE.



The following narrative has been prepared for the purpose of furnishing to those who did not take part in the journey described some notion of its interest and pleasure; of acknowledging the abundant and manifold courtesies received by the party from the governments of the Dominion of Canada, the Province of British Columbia and the Yukon Territory, and from corporations, firms and individual citizens in Canada and the United States; and of placing upon record a portion, at least, of the valuable information gained by members of the party through personal observation and inquiry, or from the official statements furnished by local committees, together with some impressions, produced by what was thus seen, heard or read.

It goes without saying that parts of this narrative may fairly be considered as representing the unanimous feeling of the members of the Institute concerned, while other parts express the individual views of the writer only. Intelligent readers may safely be trusted to make this distinction, without detailed and specific guidance.

A number of the illustrations used in this narrative have been obtained through the courtesy of the White Pass & Yukon railway, Gt. Northern R. R. and the Canadian Pacific railway; others from H. W. Du Bois, of Philadelphia; and the remainder from photographic views made by members of the party during the trip.

On Friday, June 22d, at 8.15 a.m., members and guests of the Institute residing in

New York and vicinity left Jersey City, N. J., via the Pennsylvania railroad, in a special Pullman train, comprising the following cars: "China" (1 drawing-room, 1 state-room and 12 sections); "Australia" (1 drawing-room, 1 state-room and 12 sections); "Deioces" (2 drawing-rooms and 10 sections); "Guiana" (compartment-car, 2 drawing-rooms and 7 state-rooms); "Hollenden" (dining-car); the private car "Olympia," famous through its use by the late President McKinley, Prince Henry, and other notables (3 drawing-rooms, 2 large state-rooms, and a large reception-room used alternately as a special dining-room and as a general lounging and smoking-room for the men of the party); also a large Pennsylvania railroad (Adams' Express) baggage-car. In addition to this train, which carried the party across the continent to Seattle (including the excursion into the Kootenai region in British Columbia), back from Vancouver to Jersey City, there had been also secured a special train from Nelson, B. C., to Bonnington Falls and return; a special train from Rossland to Trail Creek and return; the steamboat "*Kaslo*" for the trip on Kootenai lake; the steamer "*Charmer*" for the harbor excursion from Victoria; a special train from Victoria to Ladysmith and return; three ocean steam-ships (the "*Princess Victoria*" for the passage from Seattle to Victoria, and from Victoria to Vancouver; the "*Princess May*" for the sea-trip from Vancouver to Skagway, and the "*Princess Beatrice*" for the return trip from Skagway to Vancouver); a special train across White Pass, between Skagway and White Horse, both going and returning; the river steam-boats "*Dawson*" and "*Selkirk*," for the trip down the Yukon river to Dawson; and the "*White Horse*" and "*Dawson*," for the return to White Horse.

The whole journey, covering more than 10,000 miles, occupying 38 days, and involving, at different times, as explained above, the use of six different special trains and nine steamers, was accomplished without mishap or discomfort—a result largely due to the thorough arrangements made beforehand by Mr. Theodore Dwight, who organized the excursion, and to the executive management *en route*, in which he was ably assisted by Mr. A. E. Vaughan. Special acknowledgment should also be made of the efficient services of Mr. John Downs, an experienced baggage-master detailed from the Phila., Wilmington

and Baltimore division of the Pennsylvania railroad, who accompanied the party throughout; superintended the transfer of its baggage, large and small, at every change from train to hotel or steamer, or *vice versa;* brought back the whole collections (somewhat increased by purchases of antlers, totem-poles, etc.) without the loss of a single piece; and, most wonderful and agreeable of all, made it possible for the travelers at any reasonable time, on land or sea, to have convenient access to their trunks. The importance of this luxury, upon a tour through such varieties of altitude, latitude, and climate, can scarcely be over-estimated. For ladies especially, the ability to walk easily through a vestibuled train, and to take from, or return to, their trunks in the baggage-car whatever they chose, removed the greatest inconvenience of travel, by making it unnecessary to cumber state-rooms and sections with bags and bundles, containing provision for the ordinary or contingent exigencies of a long journey.

The following list contains the names of those constituting the special excursion-party:

Roster of Special Excursion Party.

Mr. W. P. Agnew	New York, N. Y.
Mr. T. H. Aldrich	Washington, D. C.
Mrs. T. H. Aldrich	Washington, D. C.
Miss Aldrich	Washington, D. C.
Mrs. M. B. Ayres	Bound Brook, N. J.
Mrs. S. Ayres	Bound Brook, N. J.
Mr. W. S. Ayres	Banff, Alberta, Can.
Mrs. W. S. Ayres	Banff, Alberta, Can.
Mr. D. W. Brunton	Denver, Colo.
Mrs. D. W. Brunton	Denver, Colo.
Miss Pearl Browning	Syracuse, N. Y.
Miss Elizabeth Browning	Syracuse, N. Y.
Miss J. Butchart	Victoria, B. C.
Mr. Joseph G. Butler	Youngstown, Ohio.
Mrs. Joseph G. Butler	Youngstown, Ohio.
Mr. S. M. Bamberger	Salt Lake City, Utah.
Mr. G. D. Barron	Rye, N. Y.
Mrs. G. D. Barron	Rye, N. Y.
Miss Dorothy Barron	Rye, N. Y.
Miss M. E. Barron	Rye, N. Y.
Mr. David Briggs	Chicago, Ill.
Mrs. David Briggs	Chicago, Ill.
Mr. F. J. Campbell	Denver, Colo.
Mrs. F. J. Campbell	Denver, Colo.
Mr. A. E. Carlton	Cripple Creek, Colo.

Mrs. A. E. Carlton	Cripple Creek, Colo.
Mr. F. H. Clymer	Reading, Pa.
Mr. W. B. Cogswell	Syracuse, N. Y.
Mrs. W. B. Cogswell	Syracuse, N. Y.
Mr. E. S. Cook	Pottstown, Pa.
Mrs. E. S. Cook	Pottstown, Pa.
Mr. Richard Cook	Pottstown, Pa.
Master Cook	Pottstown, Pa.
Mr. J. B. Cullum	Pittsburg, Pa.
Mr. Theodore Dwight	New York, N. Y.
Mr. E. V. d'Invilliers	Philadelphia, Pa.
Mrs. E. V. d'Invilliers	Philadelphia, Pa.
Miss d'Invilliers	Philadelphia, Pa.
Mr. B. F. Fackenthal, Jr.	Easton, Pa.
Mrs. B. F. Fackenthal, Jr.	Easton, Pa.
Mr. D. G. Forbes	Shillingstone, Blandford, Eng.
Mr. E. L. Ford	Youngstown, Ohio.
Mr. John Ford	Youngstown, Ohio.
Mr. E. L. Foucar	Denver, Colo.
Mrs. E. L. Foucar	Denver, Colo.
Mr. F. T. Freeland	Philadelphia, Pa.
Mr. C. W. Goodale	Butte, Montana.
Mr. J. C. Gwillim	Kingston, Ontario, Can.
Mr. M. H. Harrington	Philadelphia, Pa.
Mrs. M. H. Harrington	Philadelphia, Pa.
Miss M. L. Harrington	Philadelphia, Pa.
Mr. Arthur Harrington	Philadelphia, Pa.
Mr. A. B. W. Hodges	Grand Forks, B. C., Can.
Mrs. A. B. W. Hodges	Grand Forks, B. C., Can.
Mr. L. Holbrook	New York, N. Y.
Mrs. L. Holbrook	New York, N. Y.
Mr. Holt	Macon, Ga.
Miss Ida Holt	Macon, Ga.
Mrs. J. R. Howard	Brooklyn, N. Y.
Mr. R. W. Hunt	Chicago, Ill.
Mrs. R. W. Hunt	Chicago, Ill.
Captain John Irving	Victoria, B. Can.
Mr. John C. Kafer	New York, N. Y.
Mr. Paul S. King	New York, N. Y.
Mr. S. F. Kirkpatrick	Kingston, Ontario, Can.
Mr. J. Laidlaw	Cranbrook, B. C., Can.
Mrs. James M. Lawton	New York, N. Y.
Mr. John Lilly	Lambertville, N. J.
Mrs. John Lilly	Lambertville, N. J.
Mr. Wm. Lilly	Lambertville, N. J.
Major Charles E. Lydecker	New York, N. Y.
Mr. F. W. Lyman	Minneapolis, Minn.
Mr. George R. Lyman	Minneapolis, Minn.
Mr. Wm. R. McIlvain	Reading, Pa.
Mrs. Wm. R. McIlvain	Reading, Pa.
Miss Anna W. Olcott	New York, N. Y.
Mr. Chas. T. Olcott	New York, N. Y.

Master Mason Olcott..New York, N. Y.
Mr. I. P. Pardee..Hazelton, Pa.
Mrs. I. P. Pardee..Hazelton, Pa.
Master James Lee Pardee..........................Hazelton, Pa.
Mr. W. S. Pilling..Philadelphia, Pa.
Mrs. W. S. Pilling..Philadelphia, Pa.
Miss Mary B. Pilling..Philadelphia, Pa.
Mr. Joseph Ross Pilling..Philadelphia, Pa.
Mr. George Pilling..Philadelphia, Pa.
Dr. R. W. Raymond..Brooklyn, N. Y.
Mrs. R. W. Raymond..Brooklyn, N. Y.
Gen. Chas. F. Roe..New York, N. Y.
Mrs. Chas. F. Roe..New York, N. Y.
Miss Ross..Macon, Ga.
Miss Ella Sealy..Galveston, Tex.
Miss Rebecca Sealy..Galveston, Tex.
Dr. Joseph Struthers..New York, N. Y.
Miss Florence Starr..Brooklyn, N. Y.
Miss Velasquez..New York, N. Y.
Mr. A. E. Vaughan..Brooklyn, N. Y.
Mr. Walter Wood..Philadelphia, Pa.

In addition to these persons, many local members and guests attended the sessions at Victoria, and accompanied the party on various excursions and for limited distances along the route.

The schedule and the accompanying map show the places and routes concerned in this journey.

Spokane.

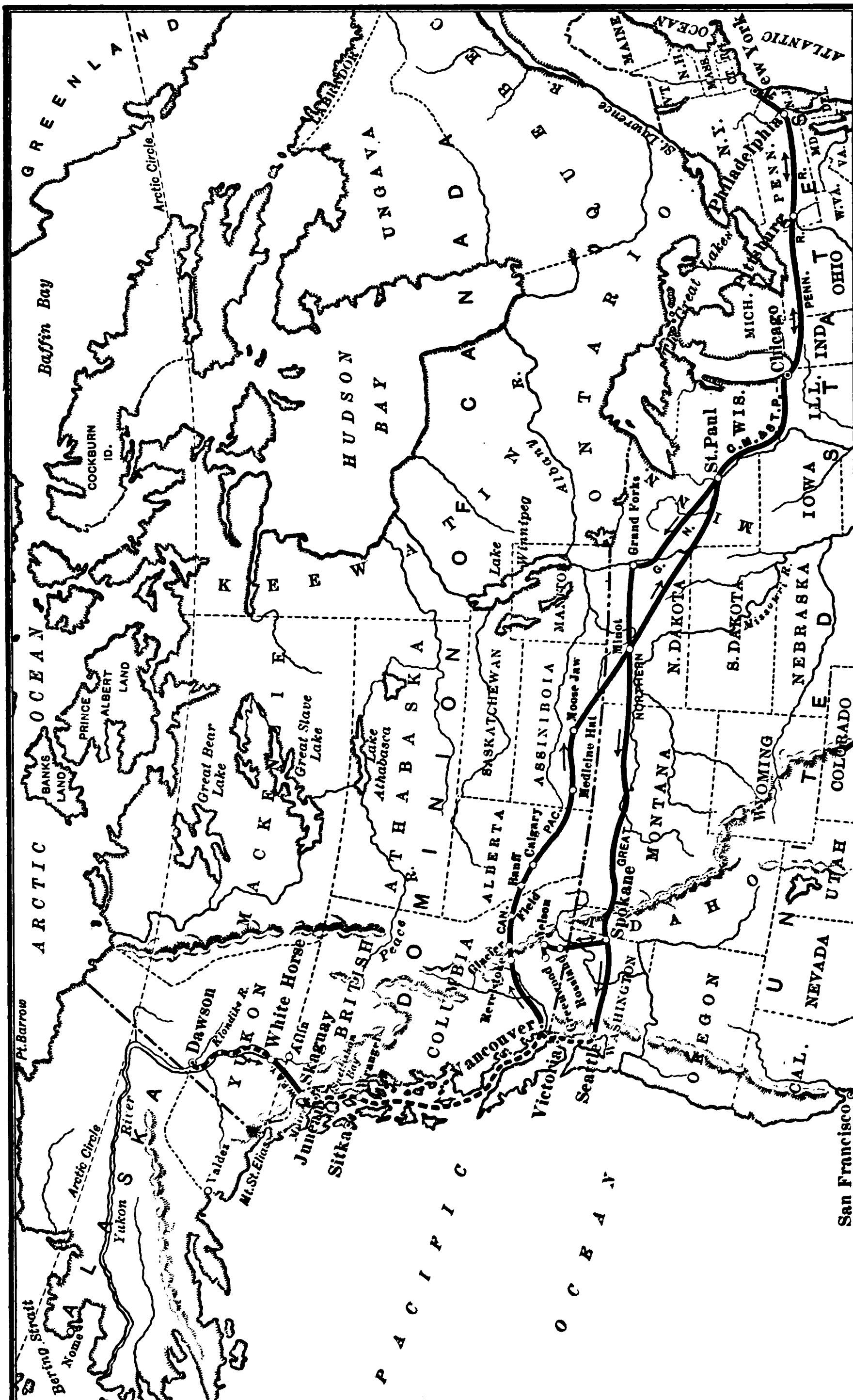
Arriving at Spokane, Wash., on Monday, June 26th, at 8.40 p.m., the party was hospitably received by the Board of Trade of that beautiful and prosperous city, and an hour was agreeably and profitably spent in the inspection of the handsome streets and buildings of which the citizens of Spokane are so justly proud, the Spokane Falls and the machinery by which they are utilized for motive power, illumination, etc.; the up-to-date fire-department, etc. Unfortunately, the lateness of the hour prevented a tour through the beautiful residential section of the city and its Park—both of which were remembered by many who had visited Spokane on a similar Institute excursion in 1899. An informal reception and collation at the railway station appropriately concluded this brief but cordial entertainment.

ITINERARY.

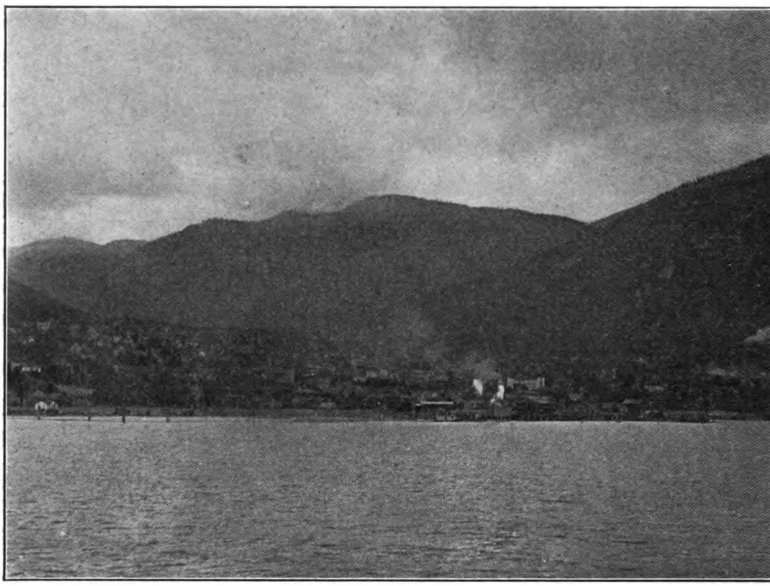
Mileage.	Place.	Day.	Time.	Route.
	New York	Lv. Friday,	June 23rd, 7.55 a.m.	
0	Jersey City	Lv. Friday,	" 23rd, 8.16 a.m.	Pennsylvania R.R.
	Philadelphia	Lv. Friday,	" 23rd, 10.25 a.m.	
	Harrisburg	Lv. Friday,	" 23rd, 12.55 p.m.	
	Pittsburg	Lv. Friday,	" 23rd, 7.05 p.m.	
912	Chicago	Arr. Saturday,	" 24th, 7.40 a.m.	
	Chicago	Lv. Saturday,	" 24th, 9.50 a.m.	C. M. & St. P.
410	St. Paul	Arr. Saturday,	" 24th, 10.00 p.m.	
	St. Paul	Lv. Saturday,	" 24th, 1.30 a.m.	Great Northern R.R.
1490	Spokane	Arr. Monday,	" 26th, 11.00 p.m.	
	Spokane	Lv. Monday,	" 26th, 9.30 p.m.	Great Northern R. R. system.
200	Nelson	Arr. Tuesday,	" 27th, 11.00 a.m.	
50	Kootenai Lake			St. "Kaslo."
	Nelson	Lv. Tuesday,	" 27th, 11.30 p.m.	Great Northern R.R. system.
89	Rossland	Arr. Wednesday,	" 28th, 10.15 a.m.	
15	Trail Creek	Wednesday.		Can. Pac. R.R. system.
	Rossland	Lv. Wednesday,	" 28th, midnight.	Great Northern R.R system.
87	Grand Forks	Arr. Thursday,	" 29th, 8.00 a.m.	
	Phœnix	Thursday.		Great Northern R.R. system.
63	Grand Forks	Lv. Thursday,	" 29th, 11.30 p.m.	
143	Spokane	Arr. Friday,	" 30th, 7.10 a.m.	
	Spokane	Lv. Friday,	" 30th, 8.00 a.m.	Great Northern.
339	Seattle	Arr. Friday,	" 30th, 8.30 p.m.	
	Seattle	Lv. Friday,	" 30th, midnight.	Str. "Princess Victoria."
78	Victoria	Arr. Saturday.	July 1st, 6.00 a.m.	
100	Harbor Excursion	Saturday.		Str. "Charmer."
100	Mt. Sicker and Ladysmith			Esquimault & Nanaimo R.R.
	Victoria	Lv. Thursday,	" 6th, 2.00 a.m.	St. "Princess May."
84	Vancouver	Arr. Thursday,	" 6th, 9.00 a.m.	
	Vancouver	Lv. Friday,	" 7th. 5.00 a.m.	
867	Skaguay	Arr. Monday,	" 10th, 6.00 a.m.	
	Skaguay	Lv. Monday,	" 10th, 10.30 a.m.	W. P. & Y. R.
110	White Horse	Arr. Monday,	" 10th, 4.30 p.m.	
	White Horse	Lv. Tuesday,	" 11th, 2.00 a.m.	Strs. "Selkirk" and "Dawson."
450	Dawson	Arr. Wednesday,	" 12th, 4.00 p.m.	Stages.
40	Around the "Dome"	Thursday,	" 13th,	
		Friday,	" 14th,	
	Dawson	Lv. Saturday,	" 15th, midnight.	Str. "White Horse" and "Dawson."
450	White Horse	Arr. Wednesday,	" 19th, 6.00 a.m.	
	White Horse	Lv. Wednesday,	" 19th, 9.30 a.m	W. P. & Y. R.
110	Skagway	Arr. Wednesday,	" 19th, 3.00 p.m.	
	Skagway	Lv. Wednesday,	" 19th, 9.00 p.m.	Str. "Princess Beatrice.."
867	Vancouver	Arr. Sunday,	" 23rd, a.m.	
	Vancouver	Lv. Sunday,	" 23rd, 12.00 noon	Can. Pacific R.R.
422	Glacier	Arr. Monday,	" 24th, 6.55 a.m.	
	Glacier	Lv. Monday,	" 24th, 12.00 noon	" " "
88	Field	Arr. Monday,	" 24th, 4.45 p.m.	
	Field	Lv. Monday,	" 24th, 6.00 p.m.	" " "
16	Laggan	Arr. Monday,	" 24th, 7.30 p.m.	
	Laggan	Lv. Tuesday,	" 25th. 4.00 p.m.	" " "
34	Banff	Arr. Tuesday,	" 25th, 5.10 p.m.	
	Banff	Lv. Wednesday,	" 26th, 4.00 p.m.	" " "
82	Calgary	Lv. Wednesday,	" 26th, 8.00 p.m.	Can. Pacific.
442	Moose Jaw	Lv. Thursday,	" 27th, 12 30 p.m.	" "
168	Portal	Lv. Thursday,	" 27th, 6.30 p.m	M. S. P. & S. S. M.
560	St. Paul	Arr. Friday,	" 28th, 2.05 p.m.	
	St. Paul	Lv. Friday,	" 28th, 8.50 p.m.	C. M. & St. P.
410	Chicago	Arr. Saturday,	" 29th, 9.15 a.m.	
	Chicago	Lv. Saturday,	" 29th, 1.30 p.m.	Pennsylvania R.R.
912	Jersey City	Arr. Sunday,	" 30th, 2.50 p.m.	
10,188				

THE KOOTENAI REGION.

At 9.30 p.m., June 26th, the party left Spokane by the Spokane Falls and Northern branch of the Great Northern Railway, and, after crossing the International Boundary (a few miles beyond Northport, Wash.), proceeded over the Nelson


ARCTIC
OCEAN
GREENLAND
Baffin Bay
Arctic Circle
LABRADOR
UNGAVA
HUDSON
BAY
COCKBURN ID.
BANKS LAND
PRINCE ALBERT LAND
KEEWATIN
MACKENZIE
Great Bear Lake
Great Slave Lake
Lake Athabasca
ATHABASKA
DOMINION
OF
CANADA
QUEBEC
ONTARIO
SASKATCHEWAN
ASSINIBOIA
ALBERTA
MANITOBA
Lake Winnipeg
Albany R.
St. Lawrence
Great Lakes
MAINE
VT.
N.H.
MASS.
CT.
N.Y.
N.J.
PENN.
MD.
DEL.
VA.
W.VA.
OHIO
MICH.
INDA.
ILL.
WIS.
IOWA
MINN.
N. DAKOTA
S. DAKOTA
NEBRASKA
Missouri R.
MONTANA
WYOMING
COLORADO
UTAH
IDAHO
NEVADA
OREGON
CAL.
WASHINGTON
UNITED STATES
ATLANTIC
OCEAN
New York
Philadelphia
Pittsburg
Chicago
St. Paul
Grand Forks
Minot
Moose Jaw
Medicine Hat
Calgary
Banff
Field
Glacier
Revelstoke
Nelson
Rossland
Spokane
Seattle
Victoria
Vancouver
GREAT NORTHERN
CAN. PAC.
C.M.&ST.P.
BRITISH
COLUMBIA
Peace R.
YUKON
Dawson
Klondike R.
White Horse
Atlin
Skagway
Juneau
Sitka
Mt. St. Elias
Valdez
ALASKA
Yukon River
Pt. Barrow
Arctic Circle
Bering Strait
Nome
PACIFIC
OCEAN
San Francisco

and Fort Sheppard Railway, through the Ymir gold-mining district, to Nelson, B. C., which was reached at 11 a.m., June 27th. Messrs. S. S. Fowler, Leslie Hill, R. R. Hedley and other members of the Local Reception Committee escorted the party to the steamer "*Kaslo*," which, decorated with flags, awaited them at the city wharf, and conveyed them through the picturesque "West Arm" of the Kootenai to Proctor's, at the entrance into the main lake, where an open-air luncheon was served; after which, before returning to Nelson, a brief voyage was made upon the Kootenai lake itself.



Nelson, British Columbia.

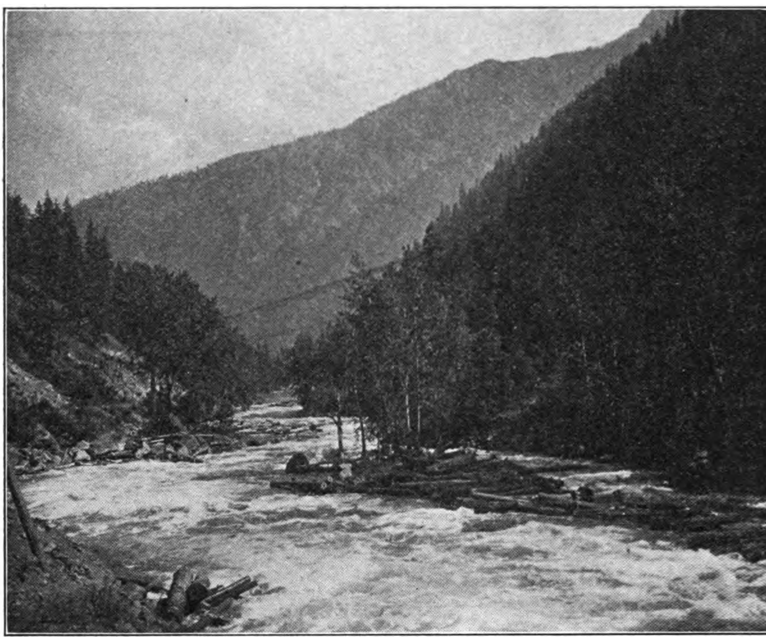
It is difficult to describe in words the exquisite loveliness and charm of this region. Coming after the long railway journey, the peace and loveliness of these lakes and rivers were, no doubt, doubly impressive. Yet no such additional emphasis was needed to enforce their enthralling charms. Neither the Swiss nor the Italian lakes can be considered as surpassing those of this district—each a perfect turquoise, set in hills of emerald, and spanned by an opalescent sky. The curious interlocking of the two drainage-systems of the Kootenai and the Columbia, with their respective enlargements into lakes, contractions into rapids and cascades, and ramifications in innumerable mountain

streams, presents a topographical complex for which it would be difficult to find a parallel. The Kootenai country is well worth a pilgrimage on account of its scenery alone. But its rich mines were the original cause of its development, and remain the basis of its prosperity. The water-ways are utilized, in connection with connecting railroads, for the transportation of ore and coal to the smelters; the water-falls offer abundant power, to be utilized and transmitted by electric currents; and the climate does not prevent continuous mining throughout the year. In

Bonnington Falls, near Nelson, British Columbia.

the immediate neighborhood of Nelson, no large mines have been opened; and the smaller operations which might become important, have been handicapped by hasty and sweeping legislation, such as the passage of an "eight-hour law" for British Columbia. Quite apart from the question of the wisdom of such laws, as applied to large and profitable undertakings, it must be at once confessed that they operate most cruelly upon enterprises engaged in "dead-work," or not yet on a paying basis. Any arbitrary prohibition, in such cases, of the employment of cheaper labor, or the employment of men who volun-

teer to work for more than eight hours a day, simply shuts up the mines which might otherwise develop into great producers. Such hasty and indiscriminate legislation has inflicted upon the mining districts of British Columbia much injury, from which they are but slowly recovering. In the vicinity of Nelson, a very healthy and encouraging sign may be recognized, in the operation of small mines upon a system of "tribute" or contract, under which operations are directed by the skilled engineer of the proprietor, while the whole working-force is paid,



Crossing the Cascades on the Great Northern Railroad.

in the lump, at an agreed rate for the amount of excavation performed, or the amount of ore produced. This total payment is divided among the workmen as they choose. It is generally understood that all the skilled miners are paid alike, without reference to the actual product of their labor. But nobody can find out what wages each man receives, because his receipts are not in wages; and nobody can say for how many hours a day the work goes on, because the men thus contracting as a body to operate a given mine will not tell anybody, or

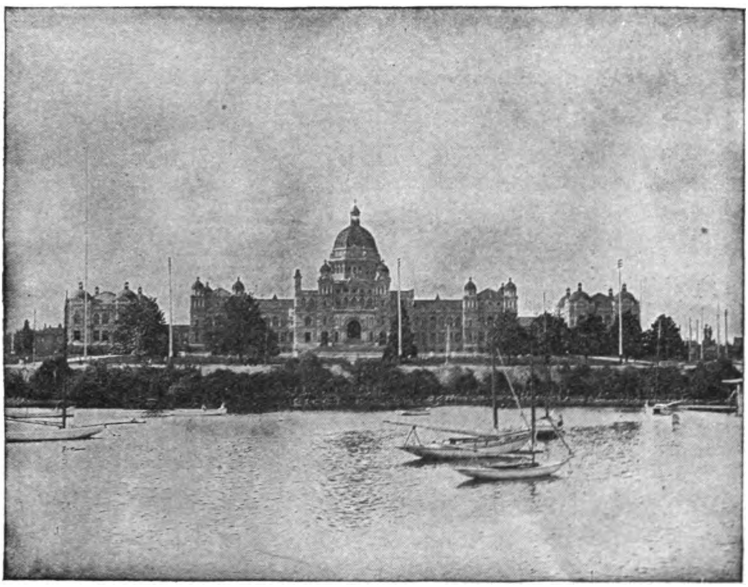
Avalanche Basin, near Bolton, Mont.

Pyramid Peak, Lake McDonald Country.

***Mt. Index**, Cascade Range,*
Washington.

permit any walking-delegate to find out by inspection, how long they choose to work. All that is known, therefore, is that a number of mines thus operated are paying profits to the owners for the first time in their history, while the working miners are receiving for their labor more than ever before.

Returning to Nelson in the afternoon, the party was conveyed on a special train furnished by the Canada Pacific railway, to Bonnington Falls, on the Kootenai river. Here the interesting power-plant of the West Kootenai Power and Light Co. was inspected, and a picnic dinner, provided by the ladies



Parliament Buildings, Victoria, B. C.

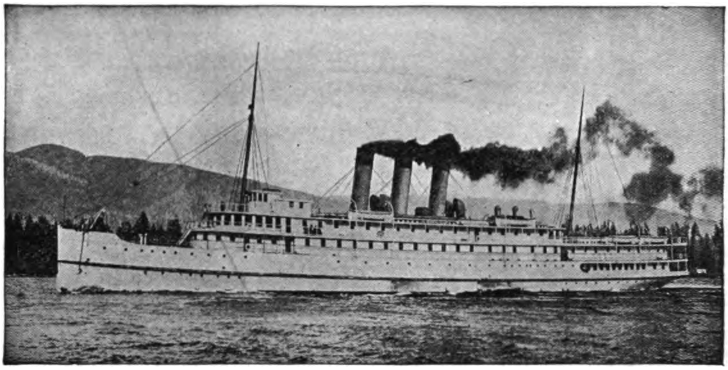
of Nelson, was heartily enjoyed, after which the train returned to Nelson. During the evening, many of the gentlemen were cordially entertained at the Nelson Club, and at a late hour the special train departed for Rossland.

Rossland.

Arriving at Rossland at 9.45 o'clock on Wednesday morning, June 28th, the visitors were cordially received by the representatives of the Local Committee.

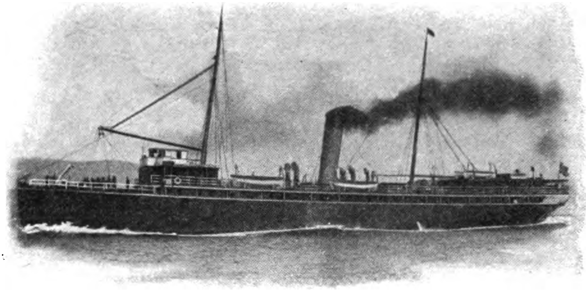
In view of the limited time which could be given to the in-

spection of the many interesting and important mines and works of the district, separate parties were organized, to visit respectively the Centre Star and the War Eagle mines, the Le Roi and Le Roi No. 2 concentrating-works (at the latter of which, Mr. H. H. Claudet, of the Canadian Ore Concentration



The "Princess Victoria."

Co., exhibited and explained the Elmore "oil-process" of concentration, there in use), or to drive about the city and along the mountain road to the site of the old Columbia and Kootenai mine, commanding a magnificent view of the Columbia

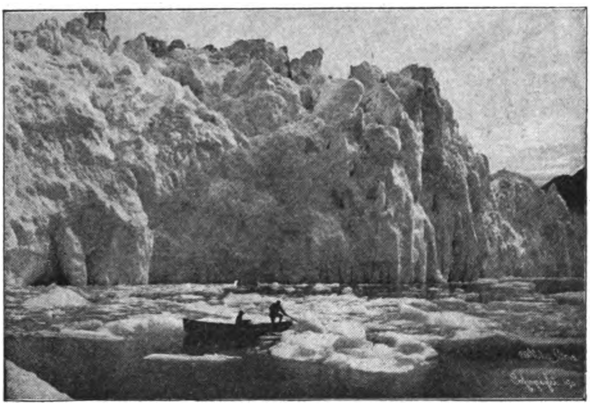


The "Princess May."

river, the Trail smelter, the valley from Rossland to Trail, and the misty mountains which frame that picture.

At 1 o'clock, a rendezvous was made at the War Eagle hotel, on the mountain, where luncheon was served; and at 2.30 p.m. a special train conveyed the party to the Trail smelting-works of the Canadian Pacific Railway Co. In the absence of Mr.

Walter H. Aldridge, chief of the mining and metallurgical department of that company, the visitors were received by Mr. J. Labarthe, Superintendent of the works, and his assistants, under whose courteous and intelligent guidance an hour or two passed quickly in the inspection of the smelting-furnaces, the electrolytic lead-refinery, and the plant for making lead-pipe. The explanation of Mr. Aldridge's much-regretted absence was furnished soon after by the announcement in the newspapers of the purchase by him, for a syndicate understood to represent the Canadian Pacific interest, of the control of three of the principal producing mines of the region. The result of this important acquisition was generally expected to be a saving in



Taku Glacier.
(Copyrighted by Miles Bros. of San Francisco).

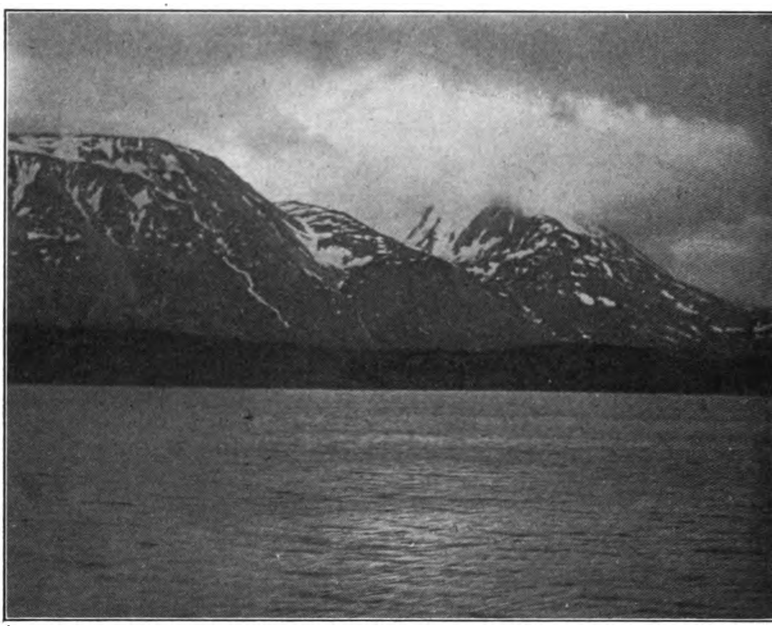
the management and a larger output from the mines concerned, and a corresponding gain in the product and technical economy of the works at Trail.

Through the courtesy of the Rossland Board of Trade, each visitor received a copy of the very able paper of Mr. Edmund B. Kirby, a member of the Institute, and lately manager of the Center Star and War Eagle mines, on "The Ore-Deposits of Rossland." From this paper (originally published in the *Journal of the Canadian Mining Institute*, vol. vii., March, 1904) the following statement has been condensed:

The Rossland district began active production in 1894, and up to January 1, 1904, yielded 1,620,540 tons of smelting-ore, of the grcss value of about $26,000,000, or $16 per ton in gold, silver and copper. Of this total, about 1,500,000

tons were shipped by four mines, the Le Roi, War Eagle, Centre Star and Leroi No. 2.

The geology of the district is peculiar. It presents an oval area of gabbro, constituting the central mass of a very ancient volcano, crystallized at great depths and now exposed by erosion, and surrounded by successive alternating bands of porphyrites and diabases, tuffs and slates. The porphyrites belong to the same magma as the gabbro, from which they are separated by an indefinite boundary (practically a zone of transition), and contain, near this boundary, the principal mines. These are located on Red mountain, above the town of Rossland, and at the west end of the gabbro mass, on which the town stands. The porphyritic country-rock is cut by numerous dikes and faults.



Lynn Canal, Alaska.

The veins are "shear-zones," produced by movement under high pressure, and subsequently mineralized, by replacement or impregnation. The chief ore-mineral is pyrrhotite, accompanied in places by small proportions of chalcopyrite, pyrite and arsenopyrite. These minerals, which were mainly introduced later than the original pyrrhotite, give commercial value in copper, gold and silver to the ore. Ore thus enriched occurs in shoots, of which several have been extensively worked. The product of the mines is concentrated in jigs, buddles, etc., and shipped for metallurgical treatment to the large smelting-works at Trail and Northport.

An encouraging feature of the larger mines is the continuity of ore to the lower levels (down to 1,550 ft. at present), and its greater value there than above.

The history of the Rossland district presents many vicissitudes, due to speculative recklessness, loose management, exorbitant labor-cost, and ignorance of the peculiar geological conditions of the ore-deposits and the treatment required by the ores. These causes have in large measure passed away. It is recognized that mining must be done on a large scale, with abundant capital for machinery, concentration-works, etc., and that the product must be treated at large establishments, where the advantages of mixture with other ores can be realized. The management of the large mines is careful and efficient;

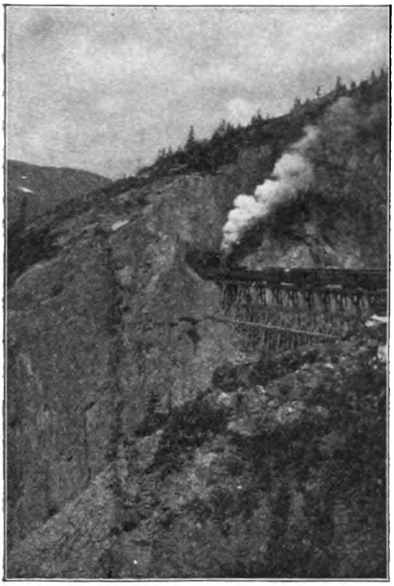
Procession of Adventurers Crossing Chilcoot Pass in 1898.

and their present condition gives promise of a considerable period of uninterrupted and profitable production. The chief cloud upon the future of the district is the high cost of prospecting and dead-work, which checks the exploration, by enterprising small capitalists, of the undeveloped ground or the mines which do not yet pay. While the maintenance of a few large concerns undoubtedly gives the best guaranty of continued production, it is the activity of many small undertakings which contribute most to the healthy prosperity of a mining camp, and leads to those discoveries and developments

which assure its future. The Provincial laws and the labor-union rules which now treat all mining enterprises alike, as if all were equally able to bear the same rate of expense, might well be so modified as to favor operations not yet profitable; for these operations need, and will repay, encouragement. The number, in the Rossland district, of mines once operated, but now temporarily abandoned, and the area of promising ground not yet adequately explored, bear significant testimony on this point.

In the evening, a banquet was given by the Local Committee at the Hotel Allan. Mr. Charles Robert Hamilton, the Mayor of Rossland, presided, and after toasts to "the King" and "the President," proposed "Our Guests," with a graceful address of welcome, to which Mr. Robert W. Hunt, past President, and, on this journey, acting President, responded. Interesting and eloquent addresses were subsequently made, on the part of the hosts of the occasion, by Hon. J. A. Macdonald, K. C., M. P. P., Prof. R. W. Brock of the Canadian Geological Survey, Mr. Anthony J. McMillan, general manager of the Le Roi mine, Mr. A. A. Cole, of the engineering staff of the Centre Star and War Eagle, Mr. William Fleet Robertson, Provincial Mineralogist of British Columbia, and Messrs. A. S. Goodeve and A. B. Mackenzie, of the Local Committee; and, on the part of the guests, by Maj. Chas. E. Lydecker and R. W. Raymond, of New York City. At a late hour, after the singing of "Auld Lang Syne," and an interesting combination of "God Save the King" and "America" (The tune is the same, and the words don't matter; every true continental American knows how to sing both at once!), the guests were hurried to their train, which conveyed them, during the rest of the night, to Northport, B. C., and Grand Forks, Wash.

It may be observed here that the Institute party, like the Columbia river, paid no attention to that imaginary line known as the "international boundary." During the journey here described, that line was crossed ten times, in one direction or the other; but custom-house delays and formalities were practically eliminated by the careful pre-arrangements of Mr. Dwight, facilitated by the courtesy of both Governments.



Approaching the Tunnel.

Hanging Rocks at Clifton.

[Views along the White Pass and Yukon Railroad.]

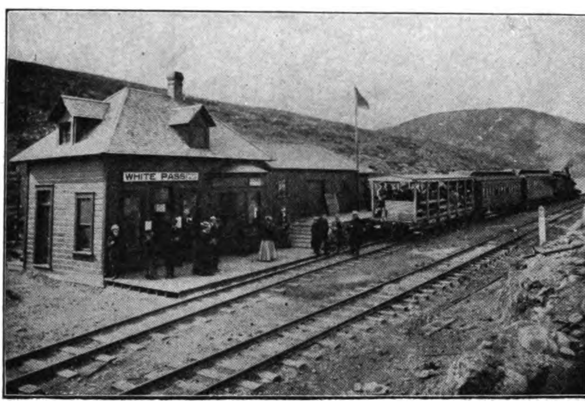
The Saw-Tooth Mountains.

Reid's Falls near Skagway.

The Cantilever Bridge.

Grand Forks.

Arriving at Grand Forks, Thursday morning, June 29th, the party was met by a reception committee, comprising Mayor Hammor and Messrs. W. T. Speir, G. M. Fripp and L. A. Manley representing the citizens, Messrs. A. B. W. Hodges, A. L. White, and other officers of the Granby Consol. Mining, Smelting & Power Co., together with a full delegation from the local press, and a number of ladies. The great smelting-works were at once inspected, under the guidance of Supt. Hodges, Assistant Supt. Williams and their staff. From the "Holiday Midwinter Number" of the *Phœnix Pioneer and Boundary Mining Journal* (January, 1905), the following notes concerning these works have been made:



The Summit of White Pass.

The construction of the first two furnaces was begun in July, 1899, and the first ore was received in July, 1900. The first furnace started August 21; the second October 13, 1900; and additional furnaces were put in blast February 27 and March 17, 1902; November 5 and November 6, 1903; October 3, 1904, and June 20, 1905, making eight blast-furnaces now in operation, together with a reverberatory and a two-stand converter plant. The present smelting-capacity is between 2,600 and 2,700 tons of ore, and the converting-capacity from 90 to 130 tons of matte, in 24 hours. Electric power is employed—about 1,100 h.p. being generated at the company's own power-house, on the north fork of the Kettle river, just below the smelter, and any necessary additional amount, up to 1,000 h.p., from the Cascade Water, Power and Light Co., which supplies at Cascade, about 12 miles from the smelter, a current of 2,000 volts, reduced by the step-down transformers at the smelter sub-station to 500 volts.

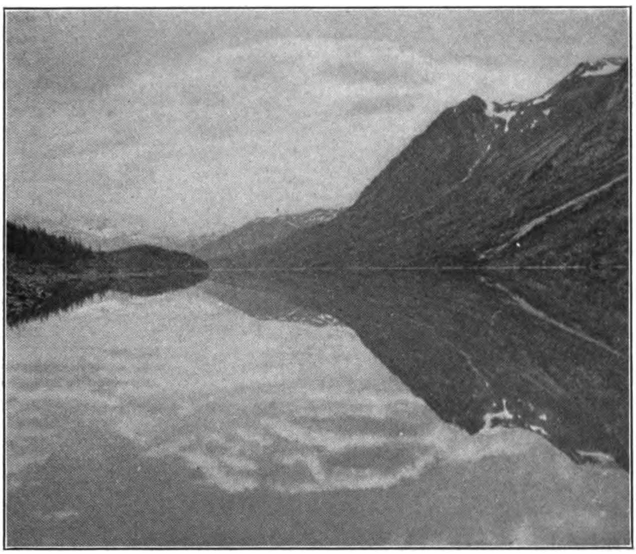
The quantities of ore treated in successive years, as shown in the following statement, were furnished by the company's Phœnix mines (with the exception of occasional small shipments from other mines in the Boundary, Kootenai and Republic districts:

Ore Treated at the Granby Smelter at Grand Forks, B. C.

Year.	Tons.
1900,	62,387
1901,	230,828
1902,	312,340
1903,	401,921
1904 (estimated),	578,000
Total,	1,585,476

For the fiscal year ending June 30, 1905, the product was officially reported as: copper, 14,237,622 lb.; silver, 212,180 oz.; and gold, 42,884 oz.

The ore of the Granby Company's mine, though running low in copper, is practically self-fluxing, and can therefore be directly smelted, while its contents in gold and silver contribute a considerable profit. These elements of commercial success have been utilized with great ability through a most impressive system of cheap transportation and handling by machinery, reducing the expense of manual labor. The automatic furnace-charger, designed by Supt. Hodges, is very ingenious and entirely successful. (A paper by Mr. Hodges, describing it, was read by title, for subsequent publication, at the Victoria meeting.)

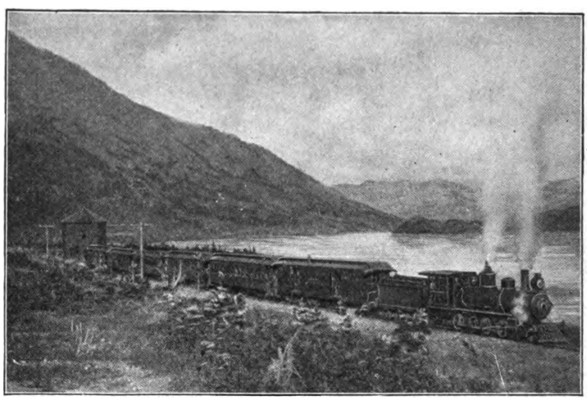


Lake Bennett.

Phœnix.

After luncheon at the offices of the smelting-works, the party proceeded in three coaches of the train to Phœnix, 30 miles from Grand Forks, by the Vancouver, Victoria and Eastern railroad.

Since the difference in elevation is more than 2,500 ft., the grades are necessarily heavy, and the line is tortuous. These facts alone would cause an experienced traveler to expect, in such a region, a picturesque journey; and these expectations were amply fulfilled, as the party was conveyed along the precipitous hillsides, up the valley of Fourth of July creek to Summit, and thence, high above Greenwood, to the head-waters

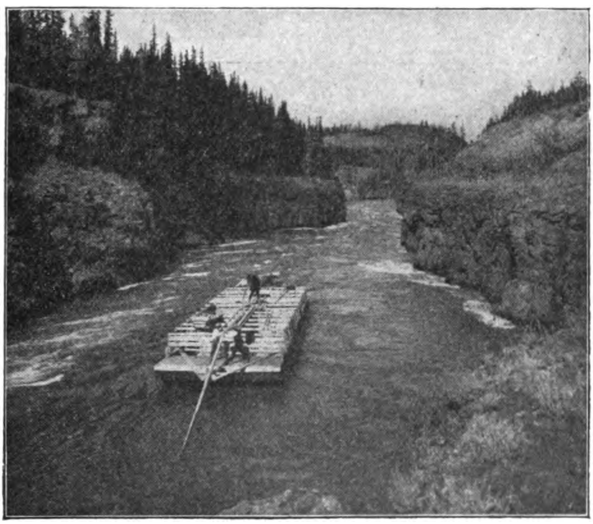


Lake Bennett.

of Eholt and Providence creeks, and so to the western end of the town of Phœnix. At the other end of town is the station of the Canadian Pacific branch. That company is said to have expended about $5,000,000 upon this and other branches in the region, chiefly for the purpose of making connection with the Granby mines and smelter. The 30 miles of the new Vancouver, Victoria and Eastern road from Grand Forks to Phœnix, belonging to the rival Great Northern system, cost about $1,000,000. Such liberal outlays not only indicate the great actual and prospective value of the industry and trade which they are intended to develop, and the far-seeing enterprise of those who take the risk involved, but also furnish, in their results, striking illustrations of a function of American railroads too often ignored or underrated by economists and legislators,

who regard them only as common carriers—namely, the function of creating and increasing production, population and trade, which could not otherwise exist or grow.

At Phœnix, the party was hospitably received by Supt. O. B. Smith and the officials of the Granby Company's mines, who conducted their guests to various points of interest, such as the "glory-hole" of the Knob Hill mine, where the steam-shovel was at work, the big air-compressor, No. 1 Tunnel, etc., and afterwards to the company's office, where the ladies of Phœnix served refreshments; and beautiful and interesting souvenirs,

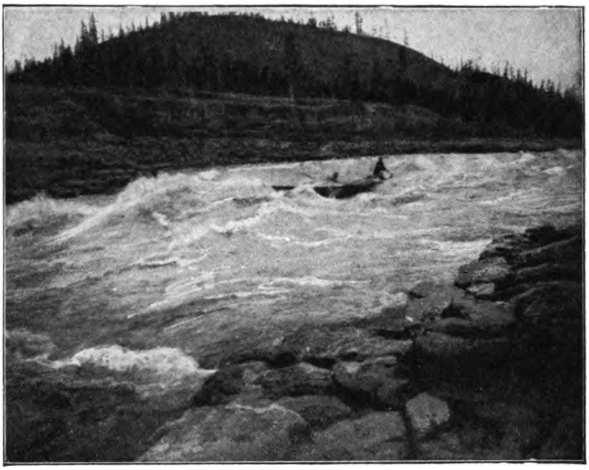


Scowing thorough Miles Canyon, near White Horse.

in the way of photographs, illustrated descriptive publications, crystalline mineral specimens, etc., were generously distributed. The maps of the mine-workings were also exhibited, and intelligent explanations were freely given to all inquiring students of the nature and form of the ore-deposits.

Without attempting here a complete scientific account of these remarkable deposits, it may be said that they contain immense masses of sulphide ore, carrying a small percentage of copper, with values in gold and silver which become important when large quantities of ore are economically treated. The weight of ore shipped by the company's mines during the year ending June 30, 1904, was (after deducting the moisture) 514,387 tons. A rough calculation, based upon the figures already quoted in connection with the smelter, indicates that this ore yields somewhat less than 1.5 per cent. of copper, 30c. worth of silver, and $2 in gold,

per ton. It is self-evident that such an ore could not possibly be mined, transported and metallurgically treated with profit, except by a complete combination of engineering and metallurgical skill, mechanical systems of handling, etc., and thorough, systematic executive management and economical control, aided by exceptionally low rates of railroad-transportation. In other words, if the railroads had been by law forbidden (as they are now practically forbidden in some of our States) to give special encouragement to this enterprise, or if their rates had been made subject to the decisions of a government commission, capital would not have been risked in the building of expensive branches; the mines would not have been worked at all; and the smaller concerns which, in some cases within the United States, so bitterly and so effectively complain of "discriminations" in favor of large concerns, would not have been thus wronged, because they would never have existed. In the relative freedom left to individual enterprise by the Imperial and Provincial governments of Canada, and the consequent activity of the railway companies of the Dominion, lies a part of the explanation



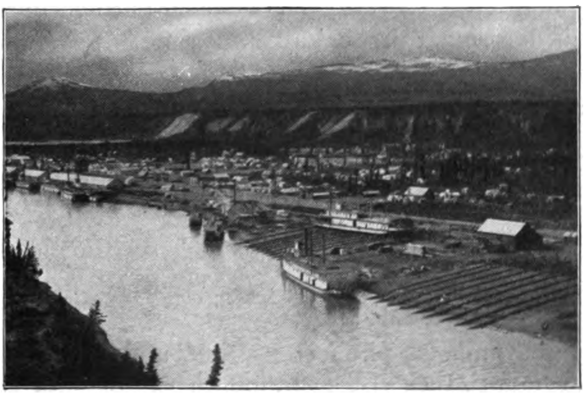
Shooting White Horse Rapids, near White Horse.

of the novel and startling phenomenon of the present unprecedented emigration from the United States into Canada.

From Spokane to Seattle.

Returning to Spokane, the party proceeded to Seattle over the Great Northern railroad, the passage of which through the Cascade range occupied the whole of Friday, June 30th. Both the engineering and the scenery of this section furnished surprise, as well as keen enjoyment, to all. With the exception of the Canadian Pacific, no one of the American transcontinental railroads can offer to its passengers, in this part of its route, such wonderful and fascinating views. Even the Cen-

tral Pacific crossing of the Sierra, as it would be if the snow-sheds were all removed, could scarcely claim scenic superiority; and as it *is*, must be adjudged to be hopelessly outside of comparison. The loops; the climbing, winding grades; the tunnels (through one of which the train goes into the heart of a solid mountain, turns about within it, and emerges not far from where it entered, only moving in the opposite direction); the lofty summits; the thickly forested cañons; the long, hazy vistas; the sudden glimpses and panoramas; the dizzy precipices and leaping cascades—following one another in swift succession—combined to create a bewildering and exciting day's experience.



View of White Horse, Y. T., taken at Midnight, June, 1902.

Seattle was reached at too late an hour in the evening of Friday, June 30th, to permit any formal entertainment of the party; but a number of the citizens were awaiting its arrival; and during the brief available interval, before the steamer left for Victoria, many of the excursionists were enabled to see something of the city. Those who had previously visited Seattle could not fail to realize the rapidity of its recent growth and progress.

VICTORIA.

The beautiful and luxurious steamer "*Princess Victoria*" conveyed the party to Victoria, which was reached at 7 a.m. on Saturday, July 1st.

The forenoon was spent in driving or walking through this attractive city and its suburbs. It may be remarked here that,

throughout the period of their stay, the members and guests of the Institute were the recipients of innumerable social attentions from the Local Committee, leading citizens and ladies of Victoria—tally-ho coaching-parties, carriage-drives for smaller companies, afternoon teas, lawn-parties, etc. These were interpolated, at every possible opportunity, between the technical sessions of the meeting and the more formal general excursions and entertainments, and were so numerous and so informal as to escape particular record, except in the memories of those who enjoyed them. No form of hospitality could have been more delightful, or better calculated to produce an indelible impression of the bright city, with its shady parks; its stately or picturesque homes; its verdant lawns and gardens fairly smothered with blossoms; its balmy and refreshing summer air; its endless variety of scenic views, lovely or grand, culminating in the unrivalled panorama of the snowy Olympic range in Washington, seen on the southern horizon, beyond the Straits of Juan de Fuca; and, above all, its genial and generous inhabitants.

The visit of a small party to the Vancouver Portland Cement Company's works at Tod inlet deserves special mention, on account of its professional interest.

Saturday evening, a public reception, under the auspices of the Government of British Columbia, was given in the Legislative Hall of the Parliament Buildings, where the venerable and beloved Sir Henri Joly de Lotbiniere, Lieutenant-Governor of the Province, assisted by Hon. Richard McBride. premier and minister of mines; Hon. F. J. Fulton, provincial secretary; Hon. R. F. Green, commissioner of lands and works, and Hon. R. G. Tatlow, minister of finance; Hon. A. E. Smith, United States consul; His Worship the Mayor of Victoria (Mr. G. H. Barnard), Mr. S. J. Pitts, president of the Victoria board of trade; Col. Prior, Major Dupont, Hon. E. Dewdney, Hon. C. E. Pooley, Canon Beanlands and many other distinguished citizens, with a goodly array of charming ladies, extended a graceful and cordial welcome. A noteworthy feature of the decorations of the building was the marvellous display of roses arranged in the *foyer* before the Legislative Hall. These were afterwards bestowed upon the ladies of the visiting party. The corridors, galleries and museums of the building afforded ample

room, not only for the suitable disposition of orchestra, refreshment-tables, etc., but also for most agreeable private saunterings and colloquies.

The illustration of the Provincial Parliament Buildings, accompanying this narrative, conveys a general notion of their admirable proportions, style and surroundings. While the effect of mass and stateliness has been retained, that of monotony has been avoided, by separating the buildings at either end, and connecting them with the central building by *porte-cochères* and galleries.

Mr. F. M. Rattenburg, the architect, was, at the time when his design was selected as the result of an open competition,

The Granite Bluffs, near Dawson, Y. T.

young and comparatively unknown. His work fully vindicates the decision of the judges in his favor. The astonishing fact that the total cost of these buildings, including their interior fittings and furniture, was but $1,000,000, indicates not only honesty, economy and loyalty on the part of everybody concerned, but also the perfection and thoroughness of the plans and specifications, and the consequent avoidance of those afterthoughts and oversights, requiring changes of detail, which almost always enhance the estimated expense of such undertakings.

The Archipelago.

Monday, July 3d, was devoted to an excursion, given by the Victoria Board of Trade, on the steamer "*Charmer*," through the magnificent archipelago lying east of Vancouver Island, and

including, among other places of historic interest, the island of San Juan, so long in dispute between the United States and Canada, but now belonging to the former country. A curious result of this political change was seen from the deck of the steamer, namely, cement-works upon the island, the product of which, being American, enjoys in the important market of the Sandwich Islands a great commercial advantage over the Canadian works which formerly possessed that market.

Professional considerations and reflections, however, played little part in the experiences of the day, which was given up to sentiment and social pleasure, inspired by glorious weather, superb scenery, complete physical comfort and the best of company. The white crests of the Olympics, already familiar, yet never to be seen too often, bounded the view for a part of the time, going and coming; and, after turning northward away from them, the steamer glided among the wooded islands and over the clear green waters of the beautiful archipelago. Similar scenery on a grander scale awaited the travelers at later stages of their long journey from Victoria up the coast; but that unknown future could not impair the admiration with which this foretaste of its glories was appreciated.

The Tyee Mines and Smelter.

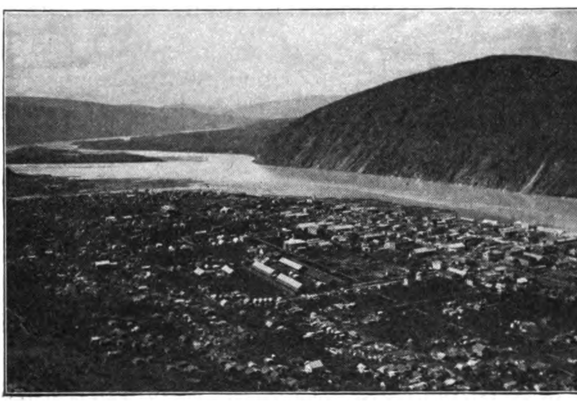
On Tuesday, July 4th, the party were the guests of the Tyee Copper Co., the general manager of which, Mr. Clermont Livingston, had arranged a double excursion, to the company's mine and smelting-works, respectively. A special train on the Esquimault and Nanaimo railway conveyed all to Duncan's, 40 miles from Vancouver, where those visiting the mine took carriages for a drive of 11 miles to Mt. Sicker, while the rest proceeded 20 miles further by rail to the Tyee smelter at Ladysmith. The line from Victoria to Duncan's follows for some distance the precipitous coast of Vancouver Island, commanding a superb view from above of the sounds, inlets and islands among which the happy voyage of the day before had been made.

The road from Duncan's to the mine passes for 5 miles through cleared land with numerous small farms, and then ascends for 6 miles through almost unbroken forest. Frequent wayside springs and streams, and a great variety of flowers in

bloom, tempted the tourists to walk and to linger; but they reached in good time the mining camp, the buildings of which had been decorated in their honor with flags and evergreens. A number of zealous mining engineers and geologists, driving through with special speed, had time to see a good deal of the underground workings. The rest were contented with a briefer inspection.

The following notes concerning this enterprise are taken from the *British Columbia Mining Record*, July, 1905, published at Victoria:

"The Tyee, Lenora, and other mineral claims on Mt. Sicker, were staked in April, 1897. After some prospecting work had been done, Mr. Livingston, seeing the promise the Tyee gave of proving a good property, bought an interest in



Birds-Eye View of Dawson Looking up the Yukon River.

it. Exploratory work was then done, with results that encouraged Mr. Livingston to proceed to London, where he succeeded in interesting capital in it.

At first a company was formed with 15,000 shares and £5,000 working capital, and a shaft was sunk 200 feet. In 1900 the shares of the Tyee Company were increased so that there were 120,000 shares. The company issued 100,000 shares and had £20,000 working capital. Mr. E. C. Musgrave, who is superintendent of the mine, joined the company in 1900, and next year he located a big ore-body, which has since been worked with good results. It is estimated that before this ore-body shall have been worked out it will have produced from 200,000 to 300,000 tons of commercial ore. Fresh stock was issued in October, 1901, increasing the company's shares to 180,000 with £50,000 working capital. Then the more extensive development of the Tyee mine was entered upon. An aerial tramway was built 3.5 miles down to the E. & N. railway; a hoisting-engine and two cages, five boilers, air-compressor, steam-pumps and other machinery were installed, contiguous claims were secured, timber-limits and land were obtained from the Esquimalt & Nanaimo railway, and the smelter was built at Ladysmith. This smelter has since treated 125,000 tons of ore from the mine.

Up to the end of April, 1905, £112,000 in profits for the last two years' work

had been sent to the directorate in London, which not only paid a dividend of 20 per cent., but also placed a substantial amount to credit of a reserve-fund, and this, too, with considerable exploratory and development-work proceeding down to the 800-ft. level, at which depth cross-cutting was lately commenced, and prospecting with the diamond drill is being done."

A bountiful collation was served in the saw-mill (near the mine-shaft), which had been transformed by graceful adornment into a festal bower, where branches and banners concealed the rough walls and the dismantled saw-frame. For the zeal and taste exhibited in this rustic decoration, the ladies of the camp deserved and received much praise.

In honor of the day, a facsimile of the American Declaration of Independence, draped in the Union Jack and the Stars and Stripes, hung behind the seat of Mr. Livingston, himself a descendant of one of the immortal "Signers," who presided and announced the first toast, to "King Edward and President Roosevelt." To this sentiment a suitable response was made by Hon. A. E. Smith, U. S. consul at Victoria; and a toast to the American Institute of Mining Engineers was acknowledged by the Secretary; after which Mr. E. V. d'Invilliers proposed the health of Mr. Livingston, Mr. E. C. Musgrave, the Superintendent of the mine, and their associates, which was drunk with cheers. The party then returned to their wagons, and swiftly descended the mountain to the station at Somenos, where the train, coming back from Ladysmith with the other excursion party, was boarded for the common return to Victoria.

The following account of the visit to the smelter (in which the writer did not take part) is condensed from the *British Columbia Mining Record* for July, 1905:

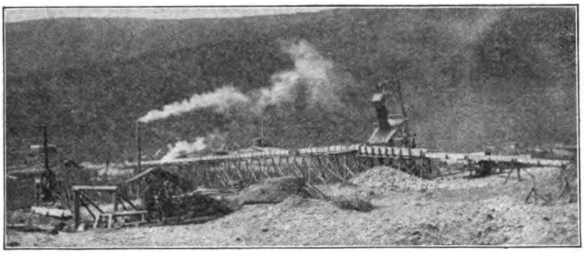
At the Ladysmith station, the party was met by Mr. Thomas Kiddie, manager of the smelter, and his assistant, Mr. W. J. Watson, and conducted through the general offices of the company, the assay-office and the works. These works, situated between the Esquimalt & Nanaimo railway and Oyster Bay, have a water-frontage of about 3,000 ft. long, besides ample room for slag-dumps for years. The ground has been laid off in terraces, permitting a gravity-system throughout, and the works were built from the designs of the manager, whose son, Mr. John Kiddie, C. E., had charge of construction, with Mr. George Williams, now mechanical engineer at the British Columbia Copper Company's smelter at Greenwood in the Boundary district. Mr. W. J. Watson is assistant superintendent and Mr. H. Collinson chief chemist.

The plant now has a capacity of 250 tons daily; but provision has been made for enlargement to 600 tons, and room left for a bessemerizing plant whenever these additions shall be deemed desirable.

The ore from the Tyee mine (which constitutes by far the larger part of that treated here, the remainder being custom ores), is brought from the lower terminal of the company's aerial tramway near Somenos, 17 m. from the smelter, in bottom-dumping 30-ton railway-cars, the proportion to be smelted raw going to receiving-bins immediately behind the furnace-house, and that to be roasted to bins above the roast-yard at the highest level of the smelter-site. A spur from the railway runs, on a rising grade, to the top of the roast-yard receiving-bins, of which there are 16, having a total storage-capacity of about 1,600 tons of crushed ore.

The ore falls from the railway-cars upon fixed screens, set in the bins at an angle of about 40°, from which the fine ore (⅜-in. size and less) falls into a separate compartment, in the center of each bin. Through the bottom-discharge-doors of the bins the ore is drawn off into ore-cars running on tram tracks, the roughs going to the roast piles and the fines to the brick-house, to be made into bricks.

The handling of ores in the roast-yard is facilitated by an ingenious system of longitudinal permanent trestles through the yard, 60 ft. apart, and movable tramway-bridges, traveling on wheels, and spanning this interval.



Mining by Machinery in the Klondike.

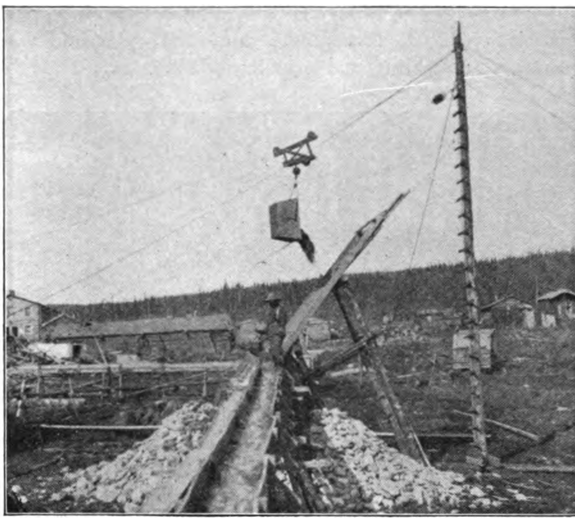
The roast-piles are 50 ft. long by 40 ft. wide and 8 ft. high, and contain about 350 tons of ore each. The object in not building them higher is to shorten the time required for roasting and, as well, the period during which the burnt ore shall necessarily be exposed to rain and consequent leaching, this latter being an important consideration where the rainfall is considerable. The ore is piled on a layer of about 12 in. of cordwood, each pile requiring about eight cords of wood. The period ordinarily occupied in burning these piles of ore is about three weeks.

The bricks of fines are roasted with the screened ores. The process of making the fines into bricks is as simple as that of ordinary brick-making. The plant consists of two 1-h.p. pug-mills and a bottom-heated drying-floor, so arranged as to equalize the heating over the whole floor space. The building housing the former is 60 by 30 ft., and that covering the latter 140 by 30 feet. The capacity of this plant is 8,000 bricks, equal to 28 tons of ore, per day. The ore-bricks are treated like the other ore in the roast-heaps. After burning, they are hard and porous, and highly suitable for smelting in the blast-furnace. The oxidation of the zinc, copper and iron in the bricks is remarkably complete, average samples of large piles of burnt bricks giving from 1.5 to 2.5 per cent. of sulphur (as sulphides), as against 7 per cent. in the ordinary burnt ore. This process does away entirely with any necessity that might otherwise exist for building and operating mechanical roasting-furnaces and the subsequent briquetting of the roasted mate-

rial. The roasted bricks are also an improvement on the ordinary briquettes, which at best are tender and very liable to make fines in the furnace, thus retarding its work. These bricks, on the other hand, stand rough handling and usage and are a valuable addition to the furnace-charge of ordinary burnt ore.

The ore from the Tyee mine has proved to be comparatively fr e-burning, and occasions little trouble by its sintering in the roast-heaps. The average of 7 per cent. of sulphur in the roasted ore does not include the sulphur of the barium sulphate, which the roasting does not affect.

The water-jacketed furnace, 42 by 120 in. at the tuyere-line, has 14 tuyeres of about 6 in. diameter. There are two water-jacketed fore-hearths. The slag is granulated by water. A brick dust-flue, 8 ft. by 11 ft. by 165 ft. long leads to an iron smoke-stack 7 ft. diameter and 90 ft. high. The engine and boiler-house is 60 ft. distant from the smelter-building. An 80-h.p. return tubular boiler supplies steam to a 14 by 36-in. Reynolds-Corliss engine, which drives a No. 7 Conners-



Mining by Machinery in the Klondike.

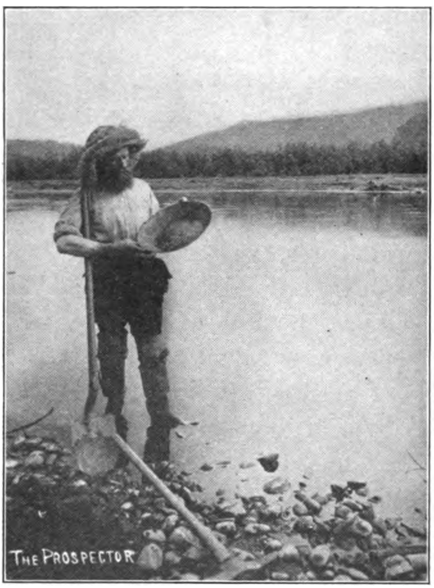
ville blower and, by means of a rope-drive, operates the matte-crushers and elevators in the smelter. A separate 17-h.p. engine runs a 200-light dynamo for lighting the works and offices.

A new hot-blast system, utilizing the waste heat of the blast-furnace, which had been in operation but a few days, was reported, as compared with the former cold-blast practice, to have reduced already the coke-consumption, besides permitting a larger proportion of raw ore in the charge, and producing a cleaner slag.

The process of matte-smelting followed at these works was the subject of a paper by Mr. Kiddie, presented in oral abstract at the Victoria meeting, and to be hereafter published. From the analyses exhibited, metallurgists could easily infer that the problem to be solved was a peculiarly difficult one, namely, the smelting of an ore containing, with 4.08 per cent. of copper,

and 10.49 of iron, 37.63 of barium sulphate, 7.36 of zinc, and 13.48 of silica; while the success of the metallurgical solution of this problem was evident in the production of a slag containing only 0.41 per cent. of copper, 0.14 (out of an original 2.67) oz. of silver, and a trace (out of 0.131 oz.) of gold per ton.

After inspecting the works, the visitors were introduced to Mrs. Kiddie, in the grounds adjoining the manager's house, where, in a gaily decorated marquee on the lawn, a bountiful luncheon was served. Mr. Kiddie proposed the health of "the King and President Roosevelt," speaking in this connection of



Prospecting on the Yukon.

the death of ex-Secretary Hay, which had been deeply felt by the British as well as the Americans. Captain R. W. Hunt responded in a felicitous speech. The Mayor of Ladysmith, Mr. J. W. Coburn, then extended a civic welcome to the visitors, expressing the hope that the trip of this party of distinguished mining men might not be without benefit, both to themselves and to the sections they visited. After an appropriate song, "Ten Thousand Miles Away," by Gen. Chas. F. Roe, Maj. Chas. E. Lydecker proposed a toast to the ladies. Col. E. G. Prior spoke eloquently of American and Canadian institutions,

and the good feeling between Canada and the United States. Speeches and songs by Col. E. G. Prior and Mr. W. F. Robertson, on the part of the hosts, and Gen. Chas. F. Roe, Maj. C. E. Lydecker, and Dr. Joseph Struthers, on the part of the guests, were followed by the enthusiastic reception of a toast in honor of Manager Kiddie and the Tyee Copper Co. At the latest practicable moment, the festive party reluctantly resumed the special train for Victoria.

Entertainments and Receptions.

After the session of Wednesday forenoon, July 5th, the Provincial Mineral Museum, in a separate house near the Parliament Building, was visited under the guidance of Mr. W. J. Sutton. One of the most interesting exhibits in the museum was an elaborate glass model of the Highland mine, at Ainsworth, in the West Kootenai district, contributed by Mr. Norman McMichael, the manager.

After the final session of Wednesday afternoon, the unbroken series of delightful experiences vouchsafed to the representatives of the Institute in Victoria was fitly crowned by a brilliant reception, given on Wednesday evening at the Government House by Lieut.-Gov. Sir Henri Joly de Lotbiniere, at which the leading members of political and social circles in Victoria, including many charming ladies (already acquainted, through their own cordial hospitality, with the ladies of the visiting party), co-operated with the genial Lieut.-Governor to signalize this cordial farewell. It must be said, however, that the genial Sir Henri scarcely needed any re-inforcement. His impartial, universal gallantry, of the graceful, antique, courtly type, captured all hearts, of both sexes; and it was not surprising to hear that both the political parties of the Province had joined in the petition that, at the approaching close of his term, he should be reappointed to his high office.* Certainly no one could more

* The chief executive officer of the Dominion of Canada is the Governor General. The highest executive title in a Province of the Dominion is "Lieutenant Governor," and, in a Territory, not yet organized into a Province, "Commissioner."

winningly represent the Province in the reception of guests from abroad.

The Victoria Government House, designed by the young architect of the Parliament Buildings, to whom reference has been made already, though not an immensely great and expensive palace, is a work of exceptional genius, perfectly adapted to its site and purpose; and its spacious halls, saloons and corridors, together with its magnificent outlook, over the sparkling waters of the Straits to the white summits of the Olympic range, made it a fitting climax and summary, for the guests of this occasion, of their memorable visit to Victoria.

VANCOUVER.

After midnight, the steamer "*Princess Victoria*" conveyed the party to Vancouver, which was reached on Thursday morning, July 6th.

The following outline of the proceedings of the day is condensed from the *British Columbia Mining Record* for July, 1905:

The joint reception committee of the City Council, Board of Trade, Tourist Association and Mining Association met the party at the wharf and extended to them the freedom of the city. At 9.30 two prettily-decorated cars, which had been provided by the British Columbia Electric Railway Co., were boarded, and while some of the members visited industrial establishments, others were taken about the city over the various car-routes. The Pacific Coast Lumber Company's saw-mill on Coal Harbor, the Vancouver Engineering Works, and the large warehouses of the wholesale hardware firm of Wood, Vallance & Leggat, were inspected.

Shortly after noon all the party gathered at the Hotel Vancouver, where they were met by many of the principal residents of the city, and after an informal reception luncheon was served. Some 200 in all were seated at the tables, many ladies and a large number of prominent citizens being present.

Mr. Colin F. Jackson, President of the Vancouver branch of the Provincial Mining Association, presided, and after a brief address, assuring the visitors of the hearty welcome of Vancouver, offered toasts to "the King and the President of the United States," which were enthusiastically received, "God Save the King" being sung in one instance and "The Star Spangled Banner" in the other.

His Worship, Mayor F. Buscombe, proposed the health of the American Institute of Mining Engineers, and expressed the belief that this visit would mark an epoch in the history of mineral development in British Columbia.

Mr. R. P. McLennan, of Dawson, Yukon Territory, here extended the invitation of that city. In the course of his remarks Mr. McLennan observed that ever since Sunday-school days it had no doubt been the dream of all to enter the golden city. Now, the engineers and their families were about to have their dreams realized, by their pilgrimage to a town whose streets were paved with gold—"fine gold" in the very soil—while, just now, there was "no night there"!

After a response by the Secretary of the Institute to these cordial addresses, guests and hosts were distributed in carriages for a drive through Stanley Park, one of the most beautiful pleasure-grounds on the Canadian coast. This park occupies the whole of a large island, partially covered with a forest of fine trees, some of which are of extraordinary size. A promontory at the end of the island, which forms one side of the narrows through which ocean-vessels come and go, commands a magnificent prospect of the extensive harbor, the mountain range beyond, and, in the farthest distance, the white dome of Mt. Baker pencilled upon the sky.

The Coast.

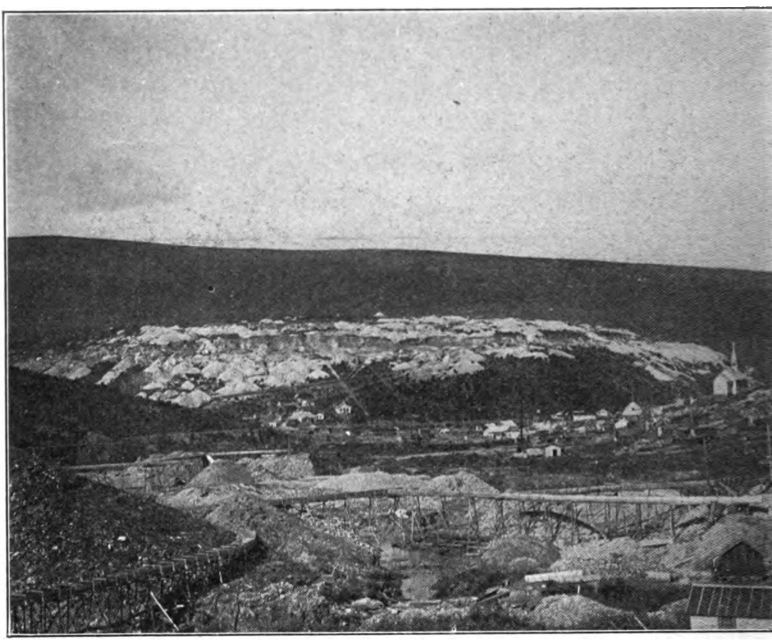
At 1.30 a.m., Friday, July 7th, the steamer "*Princess May*," began its voyage along the coast to Skagway, a distance, by the route taken, of about 900 miles. The voyage was made by the inner channel, which is almost continuously protected from the swell of the Pacific by Vancouver, Queen Charlotte, Prince of Wales, and other islands. During the two brief periods of exposure to the open ocean (in crossing Queen Charlotte Sound and the Dixon entrance, opposite Port Simpson) the waves were so quiet that the comfort of the travelers was not disturbed.

At this point it is appropriate to emphasize the extraordinary good fortune which lent to the long journey, from New York to the Yukon and back, its last touch of perfect enjoyment, in the practically unbroken prevalence of clear weather. The importance of this condition to tourists visiting Alaska is notori-

Thawing Frozen Gravel by Steam in the Klondike

ous. The great risk of that undertaking is, that the magnificent scenery may be obscured by smoke, rain or fog. Thirty-seven years ago, on his first visit to Oregon and Washington,

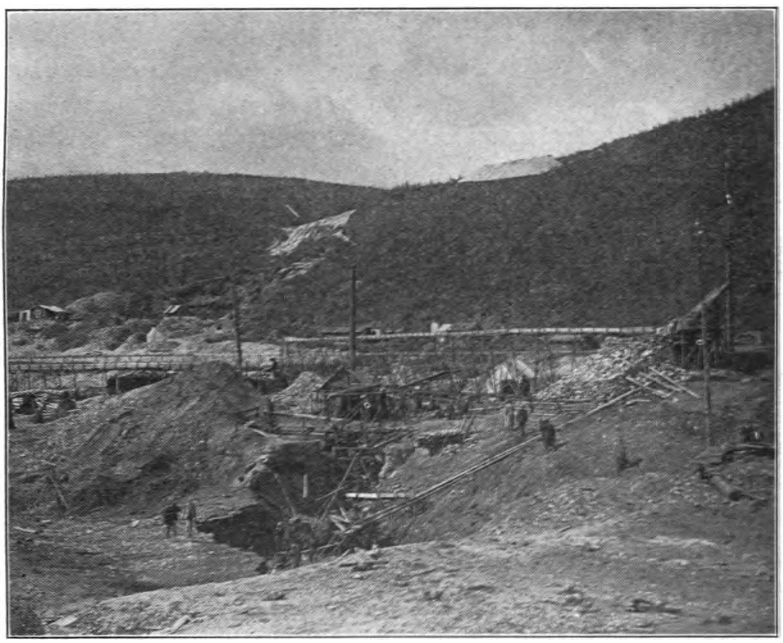
the writer experienced such a disappointment, riding through burning forests, the smoke of which dimmed the air for hundreds of miles, so that Shasta, Hood, Rainier, Adams, St. Helen's, and the splendid banks of the lower Columbia, were invisible, even from their immediate vicinity. There was much reason to fear a similar disappointment for the Institute excursion of this year. For some weeks, the newspapers had been reporting extensive forest-fires along the northern Pacific coast, which nothing but heavy rains could extinguish, and the smoke of



Grand Forks, Y. T., viewed from Gold Hill.

which dismally enveloped sea and land. During the Victoria meeting, the needed rains were reported to be falling; but their first effect was to make more smoke, and to add mist and fog to the atmosphere. Mr. McInnes, the new Commissioner of the Yukon Territory, who hastened his journey to Dawson, arriving there about 10 days in advance of the Institute party, in order to get through with his own inauguration in office, and prepare for the reception of the expected guests, encountered these unhappy conditions; and his wife, who sailed from Victoria only three or four days ahead of the Institute party,

for the purpose of assisting him in his official hospitality, was scarcely able to catch, through the fogs and rains, a glimpse of the land. Yet when the "*Princess May*" left Vancouver, smoke, rain, fog and storm had completed their work and departed, leaving a new heaven and a new earth, washed clean of every stain, and visible not only in aggregate majesty of mass and outline exhibited by peaks, precipices and glaciers, or inlets, bays and sounds, but also in every delicate detail of bower, glade, brook, tree or flowering bush.



"No. 26 above Discovery," Eldorado Creek.

For about 400 miles north of Vancouver, the heavy timber, characteristic of southern British Columbia, continues. Further north, the trees are small.

The comparison between this scenery and that of Norway is inevitable. But some of the party who had coasted that country declared vernacularly that, compared with this, Norway "was not in it;" and others retorted that if Norway were in it, Norway would be lost beyond identification in the overwhelming extent of this grandeur. This opinion is certainly not exaggerated, if to what was traversed by the Institute party be

added those portions of the Alaskan coast, west of Skagway, which it did not see—notably Prince William Sound, surrounded by the most impressive glaciers in the world.

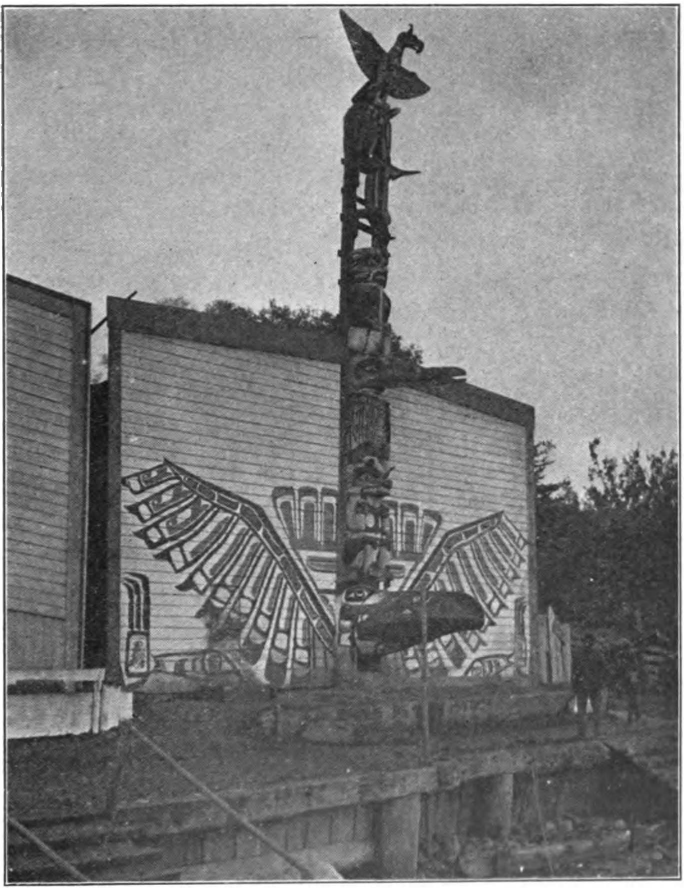
The whole voyage presented an ever-changing, never-wearying succession of fiords, bays, sounds and inlets, bounded by steep heights, up which the forests climbed, in gradually thinning ranks, until, beyond the straggling van-guard of trees, rose the stark rocky heights "above timber-line." But all the elements of beauty and sublimity were concentrated in the famous "Lynn canal," between Juneau and Skagway—a narrow passage, bordered on both sides by mountains from 3,000 to 5,000 ft. high, bearing great glaciers and banks of perennial snow, from the edges of which innumerable cascades slide and leap to the shore, threading the woods like silver ribbons, and visible sometimes only in disconnected parts, as if "stitching" the green carpet of foliage, and sometimes (as the ship reaches a new view-point) through their whole dizzy length of 3,000 or 3,500 feet. Once, a dozen glaciers, and nearly as many foaming cascades, were more or less fully visible at the same time; and there was not an hour without some new challenge to ecstatic, speechless admiration.

Brief stoppages were made on July 8th at Port Simpson, B. C., and Ketchikan, Alaska. Port Simpson is the most northern point of the coast belonging, under the recent boundary-settlement, to Canada; and is reported to have been selected as the western terminus of the new Grand Trunk Pacific road. It was hard to realize that, back of the mountains behind it, lay an agricultural region of unsurpassed productiveness. Yet this appears to have been proved beyond doubt, adding a new chapter of surprise to the history of the development of the North west.

Many of us, not yet consciously very old, remember how Jay Cooke's enthusiastic prophecies concerning the country traversed by the Northern Pacific railroad were ridiculed, and how his diagrams of northward-sweeping isothermal curves of climate were humorously characterized as indicating "Jay Cooke's banana-belt," while Proctor Knott's famous ironical eulogy of Duluth, "the zenith city of the unsalted seas," was accepted as covering with clever burlesque a serious and weighty skepticism. But that period is long past; Duluth proudly wears in

earnest the title conferred in jest; and the country developed by the Northern Pacific has vindicated the once discredited prophecy.

Then came the Great Northern, upon a parallel route higher in geographical latitude; and this, many of us thought, was surely a foolish venture. But none of us would say that now.



Totem Pole at Alert Bay, Alaska.

The Canadian Pacific, however, we could safely characterize as an enterprise justified only by Canadian pride and governmental policy, and not at all by commercial reasons. If any vestige of this wise skepticism still remained among the members of the Institute party, it was forever dissipated by the un-

mistakable evidences of business, even to the point of congestion, along that railroad.

Now comes the transcontinental extension of the Grand Trunk, still further north, and expected to pay for itself without governmental subsidy, through the immense agricultural resources of the new region it will open.

And finally, we are told by intelligent students of the Continent that there is still room to the north, and within the area of productive agriculture (especially the cultivation of wheat) for one, or even two, additional parallel lines of railway!

At present, Port Simpson is simply an Indian village; and the party found it almost deserted—the inhabitants being absent as temporary employees of the salmon-canneries, catching and dressing fish.

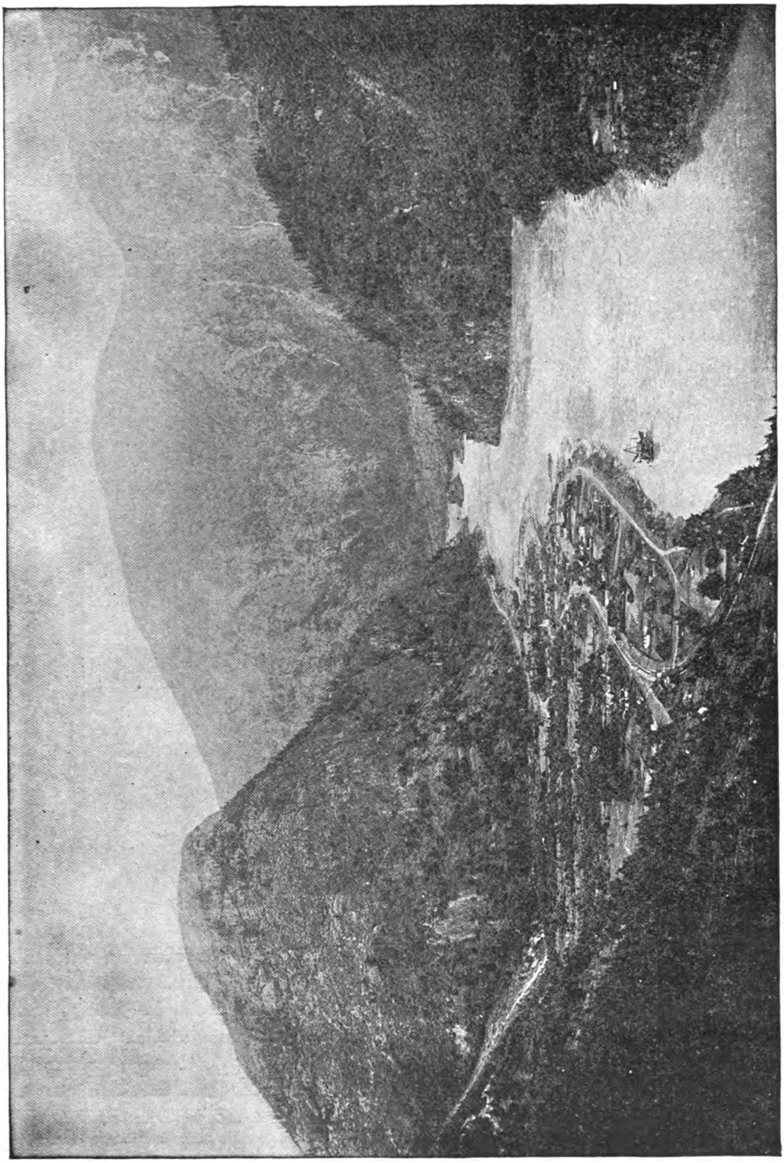
Ketchikan was reached late at night; but the citizens were awake and ready to welcome the party, many of the members of which landed and inspected with interest, not only the quaint town itself (largely built over the water and supported on piles) but also a collection of gold-, silver-, lead- and copper-ores, collected from Prince of Wales island and other places in the vicinity. The numerous promising prospects of mineral value all along the coast indicate resources which certainly deserve early attention and development, especially in view of the cheap water-transportation which gives them a valuable and immediate advantage.

At Port Simpson and Ketchikan, and at many villages along the coast, seen from the deck of the steamer, the curious Indian totem-poles were inspected with interest.

Numerous porpoises and whales were observed, disporting themselves in the clear, still water. On two occasions a fight between a whale and a "thrasher" shark was in progress as the steamer passed; and it often happened that a whale leaped wholly out of the water. To complete at once the chapter of natural history, it may be added here that afterwards, on the Yukon, a lynx was encountered, swimming to the mainland from one of the islands, and later a bear was discovered clambering up a steep bushy bluff, but a few yards from the "*Princess May.*"

On the afternoon of July 9th, the party arrived at the famous

Treadwell mine on Douglas Island, opposite Juneau, where the mine and stamp-mills of the company were inspected.



Yale and Siwash Bluff, B. C.

In view of the complete account of the geology, ore-deposits and mining and metallurgical methods of this mine, contained

in the two recent and exhaustive papers of Messrs. Kinzie and Spencer* no further description need be given here.

A considerable number of the pilgrims crossed from Douglas Island by ferry to Juneau, in which thriving town they spent a pleasant hour.

Between Vancouver and Dawson, the same route was taken (with some interesting minor variations and stoppages) both going and coming. But a special excursion has the great advantage of following its own schedule; and this had been skill-

Mount Stephen, Field, B. C.

fully utilized by Mr. Dwight, so that interesting regions were traversed, if in one direction by night, then in the other direction by day—a benefit not always conferred by the regular time-tables, and conspicuously illustrated by the trip through the sublime scenery of the Lynn canal. It must be confessed, however, that in these high latitudes, the night was neither long nor dark, and people sat up late without knowing it.

* The Treadwell Group of Mines, Douglas Island, Alaska, by Robert A. Kinzie, Asst. Supt., *Trans.*, xxxiv., 334; and The Geology of the Treadwell Ore-Deposits, Douglas Island, Alaska, by Arthur C. Spencer, *Trans.*, xxxv., 473.

The White Pass.

Skagway was reached early in the morning of Monday, July 10th. This small but busy town, crowded into the mouth of the cañon leading to the White pass, and surrounded on all sides by precipitous mountains (from one of which the great Skagway glacier looks down upon it across the quiet waters of the bay) is the western terminus of the famous railroad over the White pass to the upper Yukon. Delegates from White Horse, the other terminus, met the party here, and superintended its transfer to a special train. The White Pass and Yukon rail-

Mount Stephen, from the Eastward.

way from Skagway to White Horse (112 miles) traverses for the first 40 miles the White pass, tragically famous as one of the two passes (the Chilcoot being the other) where thousands of adventurers perished in the endeavor to reach the new Eldorado of the Klondike. The cañon is narrow and precipitous, and the steep railway-grade has been cut far above the old trail, in the granite, crossing at one point, by means of a steel cantilever bridge, a lateral ravine, through which a tumultuous cataract plunges to join the main stream. Still higher are the snowy summits and glaciers. The sublimity of these surround-

ings places this line among the foremost "scenic railways" of the world, and disposes the tourist to regard its construction as a great feat of engineering. But, in fact, to the eye of the engineer, the work appears to have presented no great difficulties, apart from its cost. For it involved simply the cutting of so much rock from a solid mass which would not cleave or slide, the building of a few culverts and retaining walls, and one bridge. Once done, it was good forever; and its maintenance is a matter of trifling cost. The great expense of keeping the line open in the winter (which requires the continuous use of a large number of rotary snow-ploughs) belongs to the summit-plateau, where snow lies deep, and not to the precipitous sides of the cañon, where snow can scarcely accumulate at all. Compared with railways in less imposing surroundings, which cross mountain-sides having what has been aptly called "finger-structure" (*i.e.*, frequently alternating ribs and ravines), necessitating innumerable tunnels and "fills" or bridges, and liable to slides of loose rock, the White pass road must be confessed to be "easy." But engineers are human; and the engineers of this party were not less ready than the rest to acknowledge the grandeur of the passage.

It was hard to realize that this rugged region, now so swiftly and comfortably traversed, had been less than ten years ago the scene of such terrible suffering and mortality. Neither the severity of the winter climate nor the difficulties of the topography adequately explain that awful story. The true explanation, given to us by several persons who had, without special suffering, made the crossing at that very period, was the incredible ignorance, inexperience, unpreparedness and reckless haste of the crazy adventurers themselves. Such frantic fools could have starved or frozen anywhere.

White Horse.

Arriving at White Horse, the party was divided into three parts, two of which were conveyed in wagons to visit respectively the Copper King and the Arctic Chief copper-mines, while the third (including most of the ladies) was similarly taken to the head of White Horse cañon, where they were enabled to witness (as spectators, or, if they desired, as passengers) the passage of a lumber-barge through the famous rapids.

Sir Donald, Selkirk Range.

The auriferous copper-belt of White Horse, extending, as far as now known, about 16 miles in a curve around the town, presents a considerable number of promising "prospects" of high grade ore, some of which will doubtless be successfully developed in the near future, especially if (as seems to be beyond doubt) the present progressive world-demand for copper shall continue. The reported

offer of a rate of $5 per ton for ore in sacks, or $6 in bulk from White Horse to the Tyee Company's smelter at Ladysmith, on Vancouver island (a distance of 112 miles by rail and 900 miles by water), leaves some margin of profit on the mining and shipment of rich copper-ores; and this operation may be expected to promote the development of mining on a larger scale, and the realization of economies in all the departments (including transportation) which will make ores of lower grade profitable.

Up to the present time, about 500 locations have been made in the belt, and about 200 kept valid by annual work. The greatest depth of workings is about 189 ft., and the total shipments of ore have been about 1,000 tons, ranging in value (for 100-ton lots) from $16 per ton for ore not sorted, to 46.64 per cent. of copper and 11 oz. silver and $2.58 gold per ton. One lot is reported to have yielded a net profit, over cost of freight and treatment, of $32 per ton.

The prevailing mineral in these ores, so far, is bornite, carrying gold and silver. Since this mineral is generally recognized as a secondary product, not likely to continue to great depth, the nature and value of the deeper parts of the deposits can only be determined by development, for which, fortunately, the rich bornite of the upper levels may furnish the means.

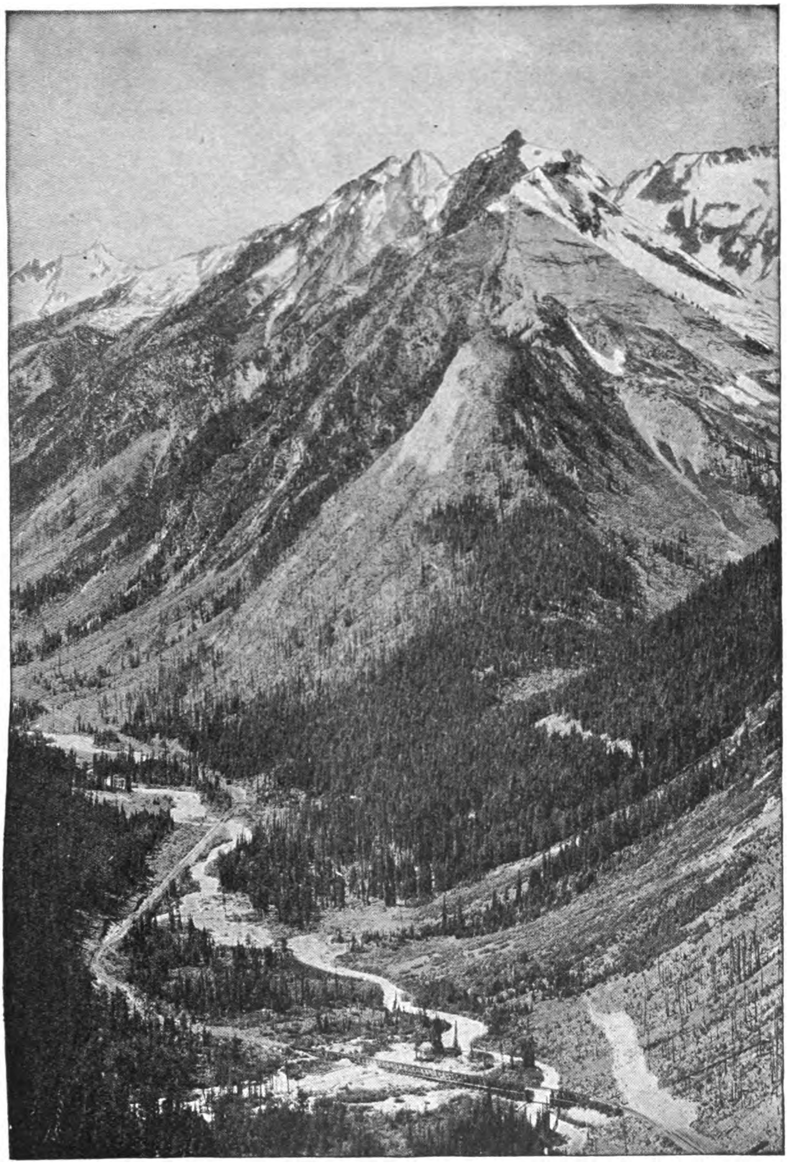
Besides these copper-deposits, there is, within 20 m. of the town, a considerable area, within which several workable seams of coal, from 16 to 18 ft. thick, are reported to exist. This coal is said to be "an anthracite in character," though the analysis given, showing only 78 per cent. of fixed carbon, scarcely warrants this classification. Other deposits, further away, are said to yield good coking coal.

Two or three weeks before the visit of the Institute party, the business part of White Horse had been almost totally destroyed by fire; and the visitors consequently arrived in the midst of the manifold and intense activity of rebuilding the town. But this did not seem to interfere in the least with the plans of municipal hospitality, which included, besides the pleasant drives already mentioned, the distribution of dainty souvenirs, printed upon silk, and setting forth the attractions and resources of White Horse, and, finally, a midnight farewell banquet, given in the club-house of the "Arctic Brotherhood," which had fortunately been spared by the recent conflagration. At this banquet the "local talent" of White Horse was most agreeably exhibited in speech and song; and Mr. Robert Lowe, who presided, presented the following address, beautifully printed upon rose-colored silk, and encased in a box, decorated with paintings of Arctic scenes—mining, traveling with dog-teams, etc.

TO THE AMERICAN INSTITUTE OF MINING ENGINEERS.

GENTLEMEN :—

The Citizens of White Horse extend to you, the representatives of the American Institute of Mining Engineers, their most hearty welcome, not only to their town, the Gateway of the Yukon, but to the Territory as a whole, on this, the



The Valley of the Illecillewaet.

first visit of your influential Association to this Great Northland, which has been in the past and will in the future undoubtedly be an important factor in the industrial and economic life of the Dominion of Canada.

Our townspeople are exceedingly gratified that your itinerary permits a short stay in the White Horse district, but regret, considering the various and vast min-

eral resources and great possibilities of the district, that more time is not afforded you to thoroughly acquaint yourselves with its resourcefulness.

We sincerely trust that your short visit may result in material benefit to yourselves as well as advantage to us.

To the ladies of your party we extend the freedom of our town, of our homes and the kindliest feeling of our hearts, and hope that they will carry away with them pleasant memories of our town and its people.

For the Citizens of White Horse.

ROBERT LOWE,
Chairman.

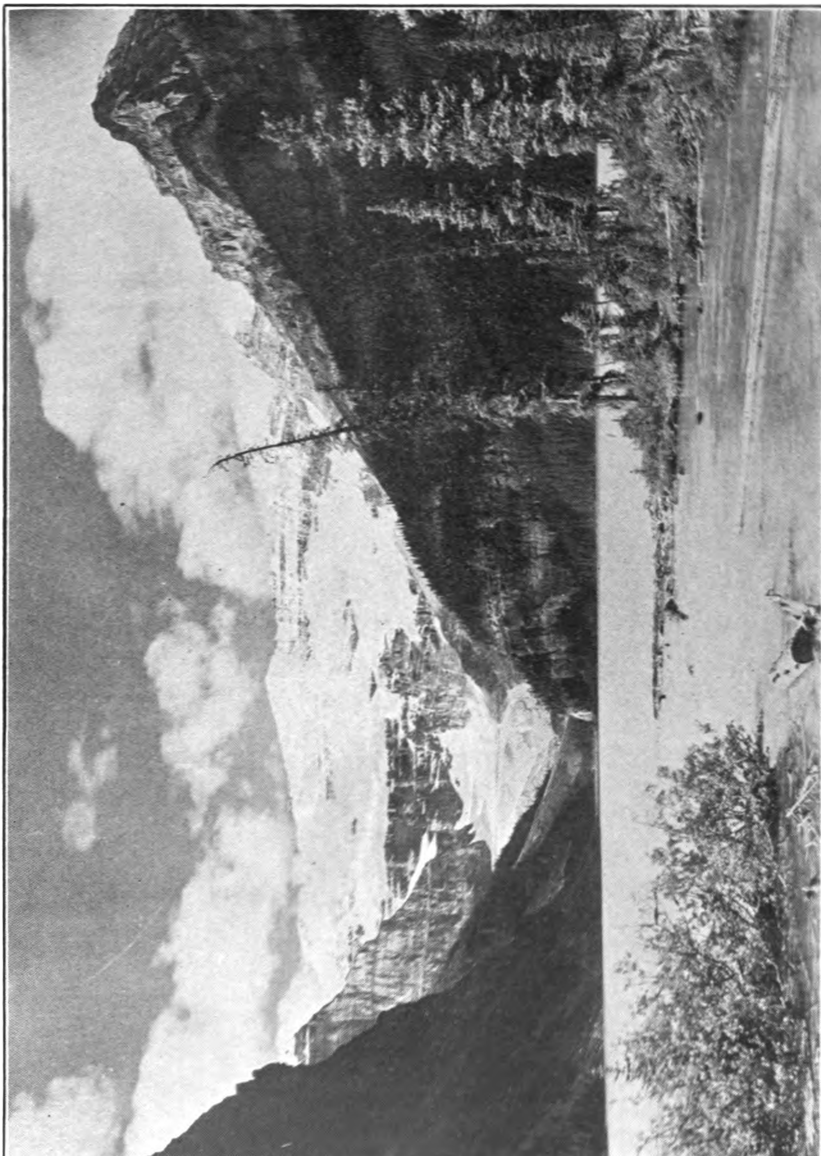
WHITE HORSE, July, 1905.

During the evening a brief shower, followed by a magnificent, complete rainbow at 9.30 p.m., emphasized to the pilgrims the high latitude they had already reached, as did, likewise, the fact that the succeeding sunset-glow, a very little west of north, had scarcely faded before the sunrise glow, a little east of north, began. Of course, the merry banqueters did not come home till morning, and could not see any difference between morning and any other time of night!

ON THE YUKON.

At some small hour of Tuesday morning, July 11th, the party, comfortably embarked upon the two sister stern-wheel steamers "*Selkirk*" and "*Dawson*," left White Horse for a voyage of 450 miles down the Yukon to Dawson, which was reached at 4 p.m. on Wednesday. The scenery of this part of the Yukon, though inferior in grandeur to that of the Coast and the Coast Range, is picturesque and varied. The river is formed by the confluence of several streams, coming from numerous elongated lakes, one of which is Lake Bennett, on the summit-plateau of the White pass, and another is Lake Labarge, beginning 25 miles below White Horse and extending 33 miles northward. Through this lake the steamer passes; and a few miles further north the Hootalinqua river, another navigable stream, enters the Yukon. From this point to Fort Selkirk, at the mouth of the Pelly river, the course of the river is tortuous, with many islands and peninsulas, and at some places considerable rapids. At Five Finger rapids the passage is very narrow; and sometimes ascending vessels have to be warped through by means of a wire cable attached to the rocky shore and passed around a capstan on board. (Upon the return voyage of the party, this operation, though not strictly necessary at the time, was performed for their entertainment.)

On the evening of July 11th, a brief stop was made at the Tantalus coal-mine, 14 miles above Five Finger rapids. Here



Lake Louise, and Victoria Glacier.
(Copyrighted by H. W. Du Bois.)

several steeply-tilted seams of bituminous coal have been opened by tunnels from the river bank. Lignite is mined below Dawson, and used in that camp.

An interesting feature of the banks of the Upper Yukon in the region drained by the Lewes and Pelly rivers, is a peculiar and persistent narrow band of white volcanic ash, underlying the soil, as exposed in the soft, eroded bluffs. This layer was noticed by Schwatka,* and has been described by Dr. George M. Dawson,† who deems it to be the result of the tranquil, wide-spread descent, like a snow-fall, of the fine ashes of a single volcanic eruption. It ranges from half an inch to more than a foot in thickness, and in some places it has been accumulated to the depth of 3 ft. and more, being in other places correspondingly thinned or removed. Apart from the general diminution towards the edges, due to increasing distance from the source (influenced also by the direction of prevailing atmospheric currents), Dr. Dawson thinks it was pretty uniform in depth; and, upon a critical consideration of all the observed facts, estimates it to cover at least 25,000 sq. miles, with an average depth of 3 in., representing a volume of 1.18 cu. miles of ash, equivalent to something less than a cubic mile of solid material. Mt. Wrangell is the nearest known volcano, and may have been the source of the deposit. From sundry indications, Dr. Dawson infers that the eruption must have occurred several hundred, yet not more than a thousand, years ago. Similar deposits of volcanic ash are not unknown. One which occurred in Alaska in 1825 is reported to have covered the whole peninsula with ashes. The ash-bed here described consists chiefly of volcanic glass, largely in elongated shreds, like "Pele's hair," together with minute crystals and crystalline fragments of sanidine, hornblende, and probably of other minerals.

Dawson.

On arrival at Dawson, Wednesday afternoon, July 12th, the members of the party were distributed to hotels and private residences, where they found most comfortable entertainment during their stay.

The afternoon was spent in visiting the numerous jewelers' shops, where unique souvenirs, made in Dawson, and exhibiting the coarse gold of the Klondike, arranged in pins, chains, bracelets, and transparent lockets, are sold. The scales and small nuggets used for this purpose, from a millimeter to a centimeter in diameter, are water-worn crystals or aggregates of crystals, which show in many instances, though much battered and deformed, the remains of faces and rounded angles.

An exhibition of specimens, hastily collected by Mr. Eugene Beraud, was also examined with much interest. It contained many samples of gold- and silver-bearing quartz; barytic lead-ores; slabs of native copper from the head of White river, looking as if they had come from one of the Lake Superior "mass-copper" mines; and curious rocks, fossils, heads of large game, furs, etc.

* *Along Alaska's Great River*, p. 196.

† *Geol. Sur. of Can., Ann. Rep., New Series*, vol. iii., part 1 (1887–8), p. 43 B.

Cathedral Mountain, Continental Divide.

The visitors were cordially received and registered at the American Consulate by Vice-consul Woodward.

At 9.30 p.m., a public reception was given at the Government House, where Commissioner W. W. B. McInnes and his

wife, assisted by Major Z. T. Wood, Commandant of the Northwest mounted police (late Acting Commissioner of the Yukon Territory) and Mrs. Wood, together with the leading citizens and ladies of Dawson, gave to their guests a delightful welcome.

The Klondike Mines.

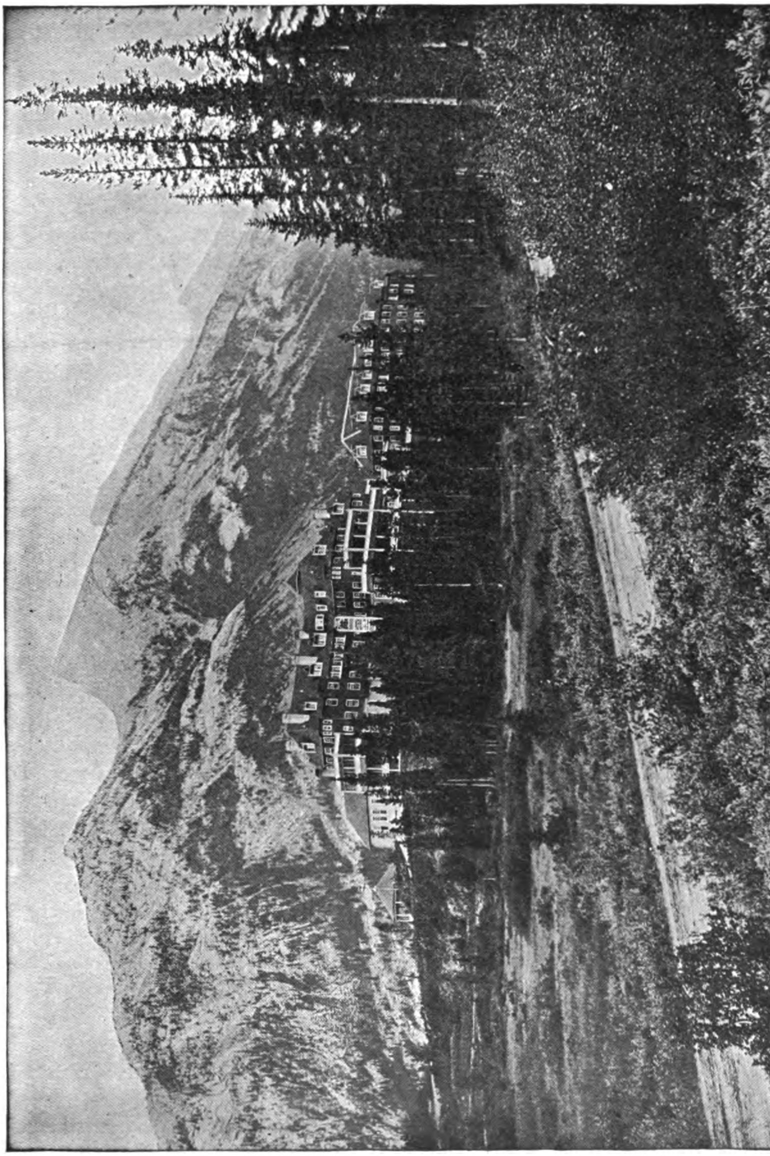
At 9 a.m. on Thursday, July 13th, the party, attended by members of the Reception Committee and other citizens, left Dawson in wagons for a drive of two days up the Klondike river, Bonanza and Eldorado creeks, thence over "the Dome," and down Gold Bottom and Hunter creeks. The night was spent at the mining town of Grand Forks, where surprisingly comfortable lodgings and excellent meals were furnished.

For the following outline of this excursion, the "*Dawson World*" and the "*Dawson Daily News*," the admirable sketch by J. C. Gwillim, M.E., in the "*British Columbia Mining Record*" for August, and the information given by the Yukon Reception Committee, have furnished the larger part of the material.

The first day presented abundant opportunity for the study of various methods of alluvial gold-mining, by open-cut, steam-shovel, scraper, traveling bucket, dredge or hydraulic jet; and "clean-ups" were made in the presence of the party, yielding respectively coarse gold of the estimated value of from $5,000 upwards. A plant of great technical interest was that of the Pacific Coast Mining Co., at claims No. 6 and 7 Below, on Bonanza creek. Here the so-called "white channel," an auriferous ancient river-bed, crossing (like the "blue lead" of California) the present topography of the country, and lying two or three hundred feet above the present streams, is worked by the hydraulic method, by means of heavy pumping-machinery, which not only lifts the water of the Klondike but delivers it, under the high pressure required for hydraulic mining, at the face of the auriferous deposit. The plant comprises a cross-compound, high-duty, fly-wheel, corliss-valve pumping-engine, with 22 by 44 in. cylinders, and 36 in. stroke, built by the Snow Steam Pump Works, Buffalo, N. Y., and having the capacity of lifting to 300 or 400 ft., at 37 revolutions, 3,000 U. S. gallons of water per minute. There are also 4 water-tube boilers, with aggregate capacity of 328 h.p.; another compound duplex pumping-engine (capacity, 1,500 gals. per min.); and the necessary machine-shop and plant for electric lighting. The company gives the cost of pumping per month as $2,200 for labor, $2,600 for fuel, and $600 for supplies, or (for 25 working days) $216 per day. This expenditure furnishes 270 miners' inches per day, representing a cost of $48 per sluice-head (60 miners' inches). The efficiency of one miner's inch of water from the middle of June to first of September is 8 cu. yards. This high duty per inch is due to the fact that the gravel rests on an even bed-rock high above the present creek level, thus giving plenty of grade for hydraulicing purposes, and that the struction of the gravel is such that it washes readily. Moreover, the ground is well thawed at this season, which makes a large difference in the daily output. The estimate based on these data by Mr. E. E. Andrews, the company's manager, shows 2,100 cu. yd. washed

per day at a cost of $216 for pumping and $200 for other items (including general expenses), or about 20 cents per yard.

This high cost could not be borne by a deposit of ordinary value per cu. yard.



Canadian Pacific Railway Company's Banff Hotel and Mount Rundle.

But Mr. Andrews estimates the amount of ground, belonging to the company, which can be treated profitably in this way at more than 1,500,000 cu. yd.—in addition to which, it possesses much other ground on the lower level, which it develops by shafts and tunnels. Unquestionably, if high-level streams, giving by

gravity the necessary hydraulic pressure, had been available, the company could have exploited the "white channel" with greater ease and profit—a proposition which emphasizes the need, and indicates the profitable character, of bringing to this region an adequate supply of water under the pressure of gravity from the mountains which surround it.

At the Discovery claim on Bonanza creek, a dredge in operation was studied with much interest, under the guidance of Mr. J. Moore Elmer, the superintendent. It is of the old Risdon type, and has a capacity of 500–600 cu. yd. in 24 hr., employing 3 men in three 8-hr. shifts. (A description of the much larger dredge now building under Mr. Elmer's direction is given in the account of the next day's trip.)

At claim No. 46 Below, on Bonanza creek, the Syndicat Lyonnaise du Klondike extended a hospitable reception, including a luncheon, followed by a clean-up from its sluices which yielded about $6,000 in coarse gold. The ladies of the party were here assisted to "pan" samples of earth shoveled from ground not yet worked. One of them obtained several dollars. This company owns also a large concession, 5 miles long by 1 mile wide, in Ten Mile creek, about 62 miles from Dawson.

Later in the day, after dinner at Grand Forks, the Stanley claim, No. 25, Eldorado creek, was visited, and a magnificent clean-up of about $20,000, from a little over 3 days' run of gravel near bed-rock, was witnessed with great surprise and delight.

At Gold Hill, the operation of a heavy stream of water brought through a 20-in. inverted pipe-siphon afforded an illustration of the economy of this method, whenever it can be employed; and at the Norwood claim, on Magnet hill, the visitors observed a similar plant, nearly completed, and including an inverted siphon, 3,500 ft. long, and expected to deliver 1,000 miners' inches of water at a pressure of nearly 300 ft. head.

On the morning of Friday, July 14th, the party left Grand Forks for "the Dome," a summit 10 miles distant, and 4,250 ft. above tide, which commands a magnificent bird's-eye view of the auriferous gulches of the region. Indeed, they seem to have their common origin in this mountain, and to radiate from it in all directions. At the summit, an abundant luncheon was served in a large tent erected for the purpose; after which, the procession of carriages descended at a rapid pace by way of Hunker creek, everywhere received with cheers and waving of handkerchiefs by the inhabitants.

Gold Bottom was reached in an hour, and a brief stop was made, to permit the inspection of old-fashioned "rockers" in operation. From No. 46 down the valley, the sound of steam-whistles from the mining-plants (at one time, there were eight going at once!) was added to the other demonstrations of welcome. At No. 76, a pause was made for the hasty inspection of the Ben Levy quartz-claim, and its ore-body; and another brief interval was given for a glance at the workings of Preido's claim, below.

At Bear creek, which was reached after 7 o'clock p.m. (but the clock had little to say at this season, when daylight lasts all night!) dinner was served, and the famous big dredge under construction was inspected with great interest.

This dredge has been built for the Canadian Klondike Co., under the direction of Supt. J. Moore Elmer, a member of the Institute. Concerning the general subject of dredging in the Yukon Territory, Mr. Elmer sent to the Local Committee an interesting statement, part of which follows:

"As a result of six years' experience, operating a 3-ft. Risdon dredge in the Klondike district, and by careful observation during that period of the aurifer-

ous deposits of the country and the climatic and other conditions peculiar to it, I am convinced that the vast Yukon basin from the Rocky Mountains to the Behring Sea contains immense areas in which the form of mining can be profitably carried on. . . .

"In California, where gold-dredging has reached its highest state of development, extremely low-grade dirt is being profitably worked, and this after paying almost fabulous prices for land which but a few years ago was considered absolutely valueless for mining purposes. True, all the conditions in California are exceptionally favorable for cheap operation. They can operate 365 days in the year, while our season is but half that length (not taking into account that during half of that time there is continuous daylight, a feature of no inconsiderable value). Our advantage lies in the high values in the ground, and it is these high values that especially commend the field for dredging operations.

"The climatic conditions are not as unfavorable as might be supposed by those

Lake Agnes and Mirror Lake.

unacquainted with the region. . . . The winters are cold but not severe, due to the dryness of the atmosphere and the absence of high winds. Blizzards are unknown. While actual dredging operations cannot be carried on during the winter, that season is ideal for the cutting and yarding of wood. Men engaged in that operation seldom find it necessary to lose a day on account of the weather. The prospecting-drill can also be worked to the best advantage during the winter.

"Our placer-gold is found mostly in bed-rock, and the ground is generally frozen. This combination of circumstances may seem to the uninitiated a fatal objection. It presents a difficulty, to be sure, but not an insurmountable one, as the results I have been able to accomplish will amply testify. It adds to the cost, but the high values obtained justify the expense.

"There are countless thousands of acres in the Yukon basin that are suitable for dredging, and that would pay handsome returns on the investment if judiciously made. The country is capable of thorough investigation, and it is the thorough and intelligent investigator that the country needs. When the true conditions become generally known, by reason of such investigation, I believe I am

not too optimistic in predicting that the number of dredges in operation in the Yukon will be limited, for a number of years, only by the capacity of the manufacturers to fill orders.

"It must not be inferred that all placer-ground in the Yukon is suitable for dredging. On the contrary, much ground that can be profitably worked by other processes would prove a failure for dredging purposes.

"In order to succeed with a dredge in the Yukon the first desideratum is careful selection of the ground as to its suitability for the purpose; then, given a dredge properly constructed to meet the conditions under which it is to be operated, and intelligently managed, the Yukon presents an almost limitless field for the profitable investment of capital in mining gold by the dredge-process."

Mr. Elmer has shown the courage of his convictions, and his company its faith in his judgment by the expenditure (as reported) of more than $250,000 on this plant. The dredge is second in size only to the mammoth machine at Oroville, Cal., which handles more than 3,000 cu. yd. of earth daily. This one is expected, under the less favorable conditions presented by the frozen gravel of the Klondike, to handle, in 24 hr., 2,000 cu. yd., digging 35 ft. below the water-surface, and throwing the tailings 22 ft. high and back 90 feet. Each of the 65 buckets weighs 1,700 lb.; and the grizzly, 27,500 lb.; and the spud, which steadies the barge from the stern, 10 tons; while many other pieces weigh from 6 to 8 tons each. The hull of the barge measures 100 by 33 feet. The electric power is generated by three 150 h.p. boilers and a 600 h.p. Westinghouse-Parsons turbine-engine.

The speed, energy and skill with which the construction of this great plant has been pushed, may be inferred from the fact that on July 9th the first material, weighing 800 tons, arrived at Dawson. Mr. McConnell, the freighter, undertook to have it all at Bear creek within 30 days, and, employing 20 teams, completed the job in 26 days. Meanwhile, the construction had to be begun; and before August 4th the frame was about 45 ft. high, and the hull was almost ready to be launched. (These latter particulars are taken from the *Denver Daily Mining Record* of August 4, 1905.)

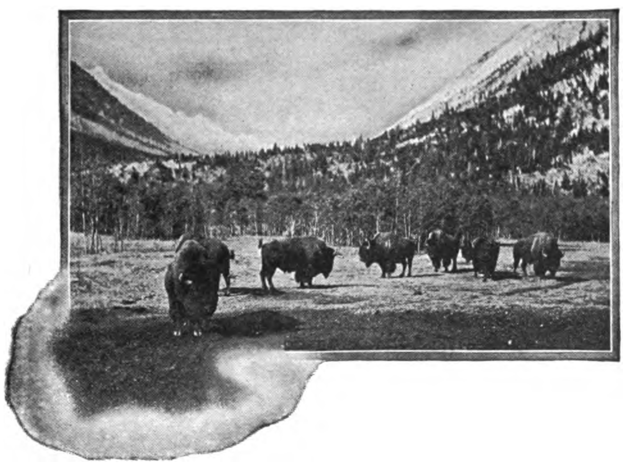
The following dredges and steam-shovels were already at work in the Yukon district: Ogilvie Dredge Co. (Klondike river); Lewes River Dredging Co. (Discovery claim, Bonanza creek); Canadian Klondike Co. (Bear creek, 2 steam-shovels); A. D. Fields (No. 60 Below, Bonanza creek); and Frank Phiscator (No. 2, Eldorado creek, 2 steam-shovels). And, besides the large dredge above described, the Williams dredge, to cost $100,000, on Klondike river, below Ogilvie bridge, and the Canadian Dredging and Mining Co.'s dredge, to cost $75,000, on No. 89 Below, Bonanza creek, were under construction.

Dawson's Farewell.

The party reached Dawson shortly after 11 p.m., but many still retained energy enough to attend a social dance, given in their honor at Eagle Hall.

Saturday, July 15th, was spent in resting, local sight-seeing, shopping, etc., and in preparations for the departure which had been fixed for that night. But before that event there was a farewell banquet, in the Hall of the Arctic Brotherhood, terminating a little after midnight. Hon. W. W. B. McInnes, Commissioner of the Yukon Territory, presided, and after toasts to the King and the President had been suitably honored, proposed "Our Guests, the American Institute of Mining Engineers," accompanying the sentiment with a graceful address of welcome, concluding as follows:

"We hope you will come again in the future, either as investors or the advisers of investors; and I can assure you, on



Buffalo at Banff.

behalf of the Government, Territorial and Federal, and on behalf of the business men of Dawson, that we will do all in our power to make such investments profitable and absolutely secure. And I have this to say also: that, whether you be on pleasure bent or on business bound, you will always find a sincere and hearty welcome!"

Acting President R. W. Hunt and Secretary R. W. Raymond responded for the Institute. Dr. Raymond's address is here printed, by request, as giving a view of the industrial situation as it appeared to the visiting engineers:

"I confess that I came with the impression that this was a region in which man was fighting a hard battle with nature, all

of whose forces and passive resistances were arrayed against him at every point. That impression has been considerably changed. I have seen that nature is not wholly hostile to you. Along with her bounty of gold, she has blessed you with an abundance of water—the agent which deposited that treasure, and upon which you must chiefly rely for its extraction.

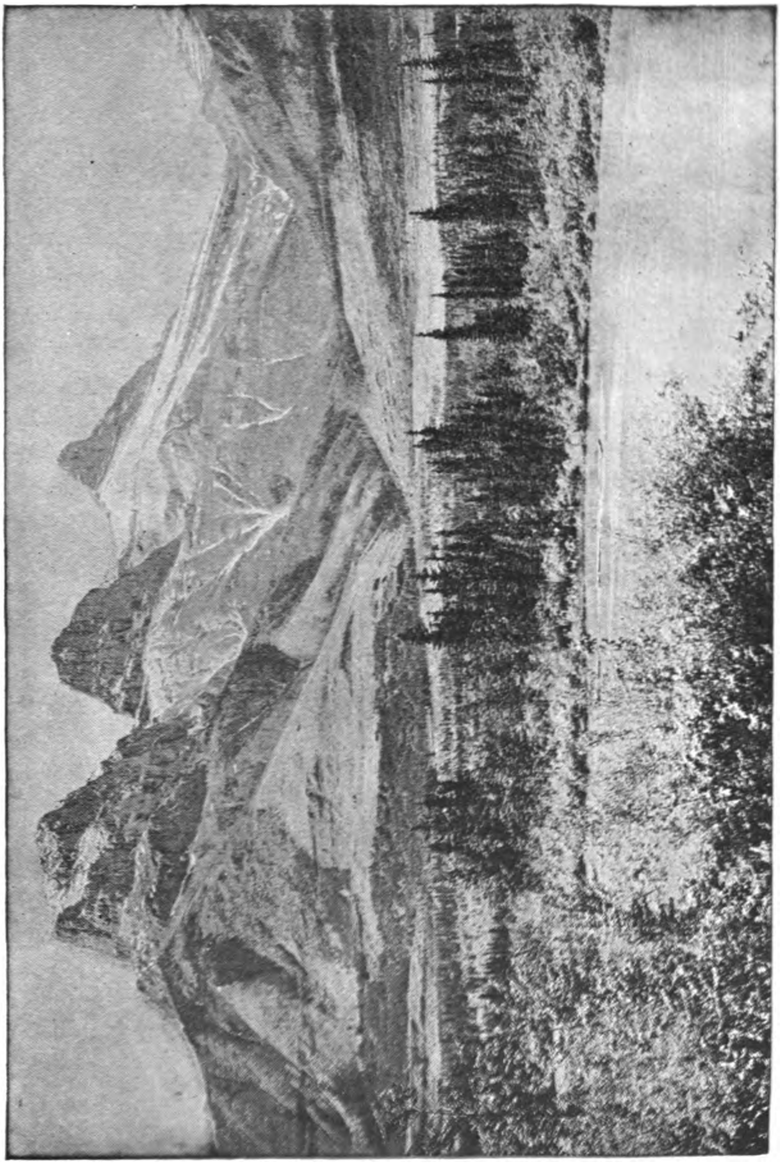
"This water furnishes you also with a trunk highway for transportation, and with sources of mechanical power, to which may be added, in your beds of coal, another essential of your industry. Man has done much already to promote the industry of your territory. Good roads, good laws, good government (with a good governor, too!), good, honest, earnest people—these things are more important, in the long run, than conditions of climate or distance.

"But I must confess to another impression with which I came here, namely, that this region was one in which a few deposits of gold of extraordinary richness were to be swiftly exploited and exhausted—probably at great expense and relatively reduced profit—after which it would be necessarily abandoned again to the Indians and the wild beasts, as no longer able to repay the labors of man.

"Is that true? It might be. There have been such regions; but I do not think this is one of them. The Yukon territory depends for its future upon the extent of the rich gold-deposits now workable at a profit; the extent of the deposits available hereafter; and the resources which may be made to reinforce these, and would be left if these were gone. The latter need not be considered now; for the former, in my judgment, ought to be sufficient for your children and your children's children.

"But rich clean-ups from placer and hydraulic mines, like rich yields in stamp-mills and furnaces, are not proofs of permanent prosperity. When only rich returns are made, it is not because everything in the district is rich, but because what is not rich cannot be worked without loss. There never was a mining district in the world that contained all rich and no poor ore, all coarse gold and no fine, any more than there ever was a cow that gave all cream and no milk. Where such concentrations of value as those which we have seen in this neighborhood are shown, you may be sure that there are immeasurably larger quantities and values scattered through inferior material; and

the mining industry becomes a really profitable business, giving steady and abundant employment to labor, dividends to capital,



The Three Sisters.

and a healthy atmosphere, both of trade and of social life, to the community, in those regions where it operates on low-grade material.

"We are all interested, of course, in seeing a skillful expert show us a dollar's worth of nuggets and scales of gold to the pan; but those of us who have followed the business of mining for years are looking quietly away from that pretty exhibition, and trying to estimate the available ground which, yielding less, ought, under suitable conditions and proper handling, to *pay* more and *last* longer. It is not what this Territory can do on a first spurt, but what it will do when it gets its second wind, that fixes its destiny for the present century.

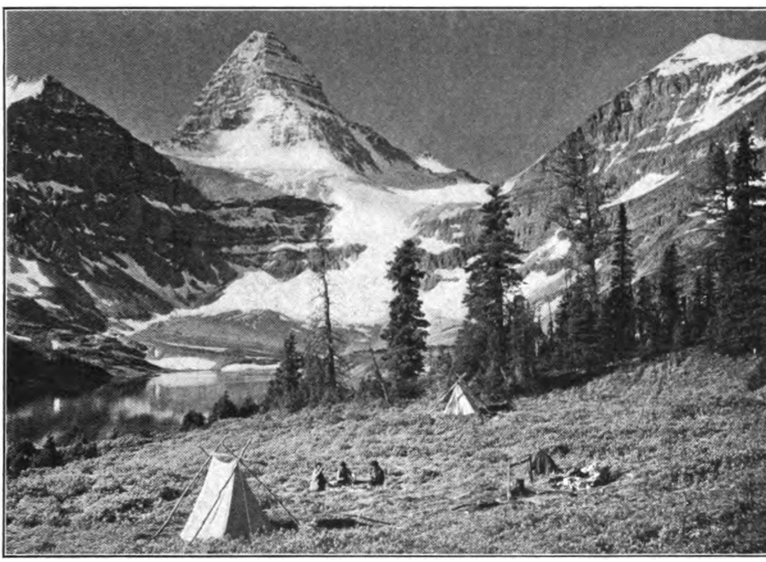
"Forty years ago a certain silver-mining district in Nevada was famous for the extraordinary richness of its ores—ruby silver, silver glance, etc. When, as United States Mining Commissioner, I visited that region, they boasted to me that not one ton of ore had ever been milled in the district that did not yield at least $125. But this proved only that they were unable to treat with profit at least nine-tenths of the ore they had to mine in order to obtain the one profitable tenth; and the yield of that rich tenth was in reality wholly wasted upon the expense of mining the rest; so that at that very time when the average yield of the ore milled was more than $100 per ton, the total bullion-product of the district was only about equal to the cost of feeding its inhabitants.

"I have repeatedly made similar calculations, with similar results, concerning mining districts in which rich material only was treated for gold or silver; and though I have not reckoned with regard to the Yukon territory, I feel quite sure that the same has been practically true here. One of the ladies of our party, returning from the brilliant excursion of yesterday and the day before, and receiving at the hotel the bill of a Dawson laundry, summed up the situation by saying, "The dirt here is certainly awfully rich, but the washing is awfully dear!" And an ingenious gentleman among us, of large diameter and corresponding surface-area, purposes to take his auriferous soiled linen out of the Territory, just as it is, and have it treated at home by somebody who will accept as pay the amount of gold to be subsequently panned out of the wash-tub!

"Seriously, what you need, first of all, is such a reduction of costs as will increase both the product and the profit of every man, whether laborer or prospector or employer, in your community. The fundamental element—the auriferous area itself

—you have in abundance, Even of the rich bonanzas you will, without doubt, discover many, rivaling those which you are now exploiting. There is cream yet to be skimmed from the top; but, if I am correct in my view, the cream will be chiefly valuable as showing you where milk is, whether in streams or in quartz! Of such milk, there is clearly a vast supply stored up for you; but to get it to market you must use what milk-men all over the world are reported to use, namely, water.

"The water question is the "burning question" of the Yukon Territory to-day. Nature has given you the means of solving



Mt. Assiniboine.

that, also, and stands ready to assist you if you work with her. You can, if you choose, raise the water by main force to the level at which you need it. We have seen a magnificent sample of that bold defiance of nature within the past two days. "*C'est magnifique, mais ce n'est pas la guerre.*" It is splendid; but, as a general proposition, it is not "biz." For water can be brought down more easily than forced up, and the water you want is not in the Klondike or the Yukon, but in those mountain streams which feed them.

"In the great enterprise of utilizing that vitally essential element of a permanent industry, I feel sure that this Territory

will receive, as I think it fairly deserves, the encouragement and assistance of the Government of the Dominion of Canada.

"It would be unbecoming for me to volunteer suggestions as to government policy, but I may be permitted to define my own view. I am not a friend of so-called paternalism or State socialism. I think that, outside of the maintenance of law and order and the enforcement of contracts, the less a government has to do, the better.

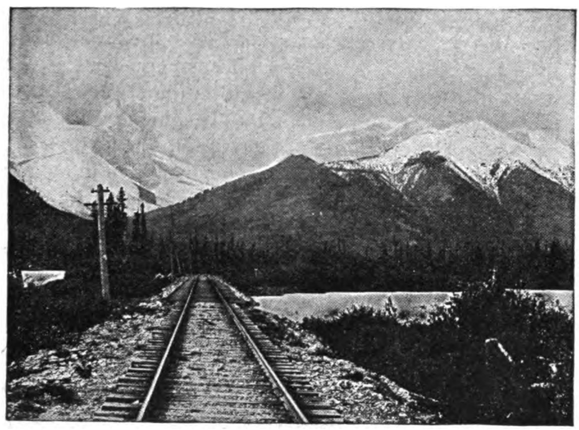
"Moreover, if I have read correctly the history of your country as well as my own, the attempt of the Government to supplant private enterprise by directly executing great works for the good of particular industries, has not resulted so advantageously as to make us yearn for its unnecessary repetition. It may have been sometimes necessary, but it has never been in itself desirable.

"On the other hand, your Government, like ours, occupies a double position. It is not only a sovereign, but also an owner of land from which it derives, through sale or royalty, a revenue. So long as the Dominion collects, as land-owner, a percentage of your product, it may fairly be called upon to manage its own property with at least ordinary wisdom, and to facilitate and assist the increase of that harvest of which it receives a part.

"I must frankly confess that my own Government has thus far shown little of this wisdom in its administration of the Territory of Alaska, from which it has received much, and for which it has done less than it might wisely do. The Dominion Government and the Governments of the Canadian Provinces have been more liberal and far-sighted. Indeed, I am inclined to suspect that, in some cases, they may have gone too far. But, in spite of any such mistakes, if any there have been, the net results of Canadian policy are seen to-day in a solid advance which has surprised your warmest friends and surpassed your own prophecies.

"In conclusion, gentlemen, let me urge upon you the importance of unanimity in pressing the just claims and supporting the vital interests of your Territory. The voice of a majority—even of a very large majority—is not enough for your need. A small dissenting minority—yes, even a siugle strident opposing voice—can work immeasurable mischief in the consideration

by a distant executive government, or the discussion by a distant parliament, of proposals and requests affecting the interests of a newly opened, largely undeveloped and little-known region. If *you* cannot agree about yourselves, how can you expect remote strangers, however well disposed, to agree about you? I trust you will not deem me impertinent when I say that, in my judgment, any division among the citizens of the Yukon Territory on the lines of political parties elsewhere—in Victoria, Ottawa or London—would be the height of folly. Why should anybody be "Conservative," for instance, in a country which



Farewell to the Rockies.

has no past to "conserve," but only a glorious future to conquer?

"On the other hand, if you act together, in warm—yes, white-hot—yes, *fluid*—unanimity, obliterating all distinctions of personal ambition or party politics, there is nothing you can properly desire which you will not irresistibly achieve!

"Our generation has had an object-lesson concerning the power of such unanimity, which we may well heed. We have seen the small nation of Japan victorious over a more powerful but less enthusiastically united foe. I know of nothing in the history of war more wonderful than the skill, devotion, tenacity and patience which lately captured one of the strongest fortresses in the world. If there be a parallel, we must seek it in the annals of peace, a thrilling chapter of which records the conquest of this region by the dauntless and perse-

vering pioneers of the Yukon and the Klondike. Be of good cheer! You have won your Port Arthur; and it now remains for you to make a permanent ally of that Nature which was at first your foe, and to arrange with her and with one another the wise terms of a permanent and profitable peace!"

Hon. J. T. Lithgow, Comptroller of the Territory, in proposing the toast of "The Mining Industry," said:

"I desire to join with you, Mr. Commissioner, in expressing the gratification which is felt by the residents of the Yukon Territory in the visit of the American Institute of Mining Engineers. It is very gratifying to us that the ladies have accompanied the party, and we trust that their visit will prove both pleasant and profitable. It is a matter of regret to me that I have been asked to propose this toast, since during my seven years' residence in this territory I have had practically nothing to do with mining, except to collect the royalty from miners after they had extracted the gold from the ground. (Laughter.)

"The first strike of gold was made in this district on August 15, 1896, by George Carmack and two Indians. Many other prospectors had been in the country; and it is really due to the adventurous spirit of Bob Henderson (who was engaged in mining on what is now known as Hunker creek, and who had visited the mouth of the Klondike, where the Indians were camped) that the rich discovery was made which electrified the world.

"A number of miners from Fortymile, Eagle, Circle City and other places, on hearing of the strike, came up here, and spread the news to the outside world. Then took place one of the greatest stampedes ever known since the discovery of gold in California in 1849, and later in Australia in 1862. It is estimated that some 80,000 men, many of whom were utterly unable to cope with the great difficulties incidental to placer-mining in those days, rushed into this region.

"The introduction of steam-thawing apparatus, hoisting- and pumping-machinery, etc., and the discovery of gold on the higher levels, greatly helped to increase the product of the Territory.

"The first creeks to be worked were Bonanza and Eldorado. From the latter creek, which was developed for three and one-half miles, it is estimated that there came $25,000,000. I know of one claim, 500 ft. long, which produced a million. This figure is based on the royalty actually paid—certainly a very good basis on which to calculate the product of this claim. The fact that you engineers have visited the creek and found it still being worked with a large output, further testifies to its great wealth.

"The total gold-production of the Yukon Territory, up to the 31st December, 1904, is placed at $114,186,000. This, I think, is certainly a very conservative estimate, much below what was actually produced. Those of us who have resided here since 1898 realize that the first very rich claims are nearly worked out, but that the lower-grade gravels, if worked economically, will produce millions and millions for years to come. The introduction of dredges has begun, and they are now successfully worked.

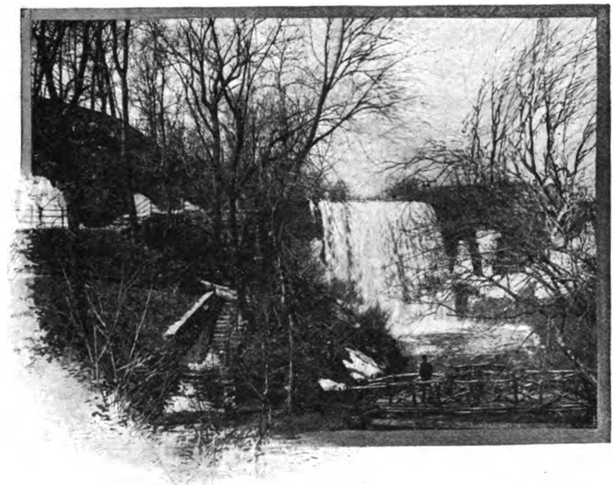
"This is the present position of our placer-mining. It is a matter of regret that the engineers did not have time to visit the outlying districts and be convinced that what they saw in the Dawson district was but a drop in the bucket.

"Those of us who have a knowledge of the Duncan, Hiatt and other tributa-

ries of the Stewart river, are aware of the immense deposits which are yet to be opened. After a time we shall hear of the development of the Kluane and other large districts, many of which are as yet unnamed, but are known to contain auriferous gravel deposits.

"There are many indications of good quartz-veins in the country, and the time is not far distant when stamp-mills will be in operation. The rich deposits of copper at White Horse, the abundant supply of suitable coal and fluxing material in close proximity, and the occurrence at various points of high-grade silver-lead ores, lead us to believe that, in a very short time, these products will add materially to the mineral riches of the Yukon."

Mr. C. W. Goodale, Gen. Manager of the Boston and Montana Copper Co., replied to this toast, adducing the Butte district of Montana as an instance of the development of other



Minnehaha Falls, Minneapolis.

mineral resources than those which first attracted miners to it. Butte began with placer-mining for gold; then became a silver-mining camp, when the first ore-bodies were found; and is now justly famous for its production of copper. Mr. Goodale urged the importance of explorations for deep deposits of gold, silver, copper, lead, etc., while the exploitation of the placers was still active, and before the approaching exhaustion of such mines should cause diminution of population, scarcity of labor, and lack of speculative interest and energy, in order, as he expressed it, that the two kinds of mining "might overlap, and thereby give continuity to the prosperity already enjoyed by this camp."

Mr. E. V. d'Invilliers, of Philadelphia, Pa., being also called upon to reply to the toast of "The Mining Industry," responded with brief but interesting remarks, vindicating the fundamental importance of coal as a primary necessity to the development of all mineral industries, and expressing a strongly favorable opinion of the value of the Yukon coal-fields.

Dr. Joseph Struthers, Assistant Editor of the *Transactions* of the Institute, and formerly Editor of the great American statistical publication, "The Mineral Industry," being called upon, responded with a pertinent and forcible recommendation of the preparation and circulation of trustworthy statistics as a much more effective agency of real progress in the development of a new mineral region, than the imaginative and exaggerated accounts of enthusiastic prospectors or interested promoters. In this respect, the carefully prepared, temperate and comprehensive pamphlet of the Yukon Committee was worthy of high praise.

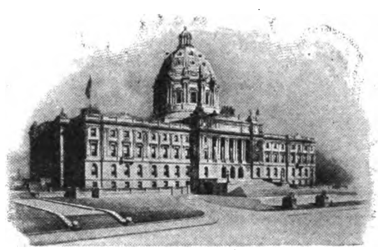
Mr. D. W. Brunton, of Denver, Colo., a past Vice-President of the Institute, was likewise called upon, and expressed for himself and his associates the favorable opinion of the natural resources and industrial, commercial, governmental and social conditions of the Yukon Territory, which they had formed during their visit.

Mr. Charles Macdonald, of Dawson, speaking for Dr. Antony Variclé, presented to the Institute a magnificent album of photographs of Yukon scenery, etc. This folio, about 22 by 33 in. in size, is bound in flexible caribou-leather, embossed and decorated, the central design being a placer-miner's pan, containing scales of Klondike gold, while from this pan a stream of gold (in particles cemented to the caribou-leather) descends to the lower edge of the cover. Among the photographs, which are not only typical and interesting, but remarkably fine, artistically and mechanically, is a panoramic view of Dawson and vicinity, 11.5 in. wide by more than 5 ft. long, and necessarily constituting a "folder."

Dr. Variclé, who has been elected a Life Associate of the Institute, is a highly-esteemed citizen of Dawson, heretofore known in scientific circles as a member of the Aeronautical Society, and an author on that subject, but more recently distinguished as the originator of a new scheme of Arctic exploration, of which an early practical test (in 1906) now seems probable. The essential novelty of the plan consists in the utilization of the method employed by the Northwest

Mounted Police in many adventurous explorations not as famous as they deserve to be—namely, the employment of both mules and dogs for transportation, and the killing of the mules as food for the dogs, when there is no longer forage for the former. Of course, a "dash" thus supported would start from a base of supplies previously established as far north as practicable. Before hearing of Dr. Varicle's enterprise, the writer had received from an officer of the Mounted Police an intensely interesting account of this method of exploration, at the close of which he asked, "Why haven't you ever gone to the North Pole in that way?" The serious *naive* reply was: "Well, we never have been ordered to do that!" The further question, "If you should receive such orders, do you think you could carry them out?" elicited the answer, "I think we could probably go as far as there is any land." This touches the heart of the problem of reaching the Pole. But there seems to be little doubt of the success of the method for the extension of Arctic explorations on land, at least.

The banquet had been inaugurated by a march around the tables of Mr. Anderson, a Scotch citizen of Dawson, and a famous piper (whose brother was said to be piper to King Edward), over 6 ft. tall and of splendid physical symmetry, who was dressed in full Highland costume. The same magnificent figure tunefully led the procession which marched, after the feast, to the steamboats at the docks. Midnight had nominally passed; yet sufficient day still lingered in the sky to permit a photograph of the scene to be taken. The people of Dawson (who apparently did not go to bed at all during the visit of the party) lined the streets, and subsequently crowded the piers, bidding their guests farewell with waving handkerchiefs, songs and cheers; and when at last the two steamers cast loose, and began their return-journey up the Yukon, the vanishing picture of this hospitable multitude worthily closed a unique and unforgettable episode.



State Capitol, St. Paul.

Homeward Over the Canadian Pacific.

The return-trip to Vancouver presented few novelties inviting description. One of these was the exceptional view of Lake Bennett, on the summit of the White pass, which happened to be (almost beyond the recollection of the railway-people, who see it every day) unruffled by any breeze, and, consequently,

presented in its transparent depths a perfect reflection of the surrounding mountains and the sky above them. Another was the entrance into Taku Bay, where, amid iridescent icebergs, the steamer floated close to the precipitous face of the great Taku glacier, where it breaks off into the water. And a third was the inspection, at Alert Bay, of a modern salmon-cannery, with its Indian fishermen, encamped with their families in deserted houses; its heaps of freshly-netted fish of gorgeous hue; and its apparatus for swiftly preparing and canning them. There were also at Alert Bay totem-poles, finely carved canoes, and an Indian burying-ground.

Arriving at Vancouver, late Saturday night, July 22d, the party was transferred Sunday afternoon to the special train (the same which had conveyed it westward from New York), and proceeded eastward that night on the Canadian Pacific railway.

It is unnecessary to describe here the sublime scenery of the Frazer cañon, the Selkirks and the Canadian Rockies, through which the main line of this railway passes. The accompanying illustrations represent a few of the many scenes, formerly accessible to hardy and adventurous explorers only, but now to be reached with ease and comfort by ordinary tourists. While it is confessedly impossible to compare, for the determination of their relative rank, the master-pieces of Nature's architecture and painting, this much may be fairly said: that, even after all the glories of the long preceding journey, the members of the Institute party enjoyed during their return-trip new experiences of reverent delight, and were justified in regarding this final period as the climax and crown of all that had gone before.

Stops were made by the special train at Glacier, Field, Laggan, Banff, Calgary, Moose Jaw and Portal, at the times shown in the itinerary already given.

Aside from the æsthetic and social enjoyment of this part of the homeward journey, two points deserve special mention.

1. The first concerns the admirable arrangements of the Canadian Pacific Railway Co. for the utilization of the great scenic attractions of its road. In addition to its well-appointed sleeping- and dining-cars, and its efficient general passenger-service, this company has provided good hotels, roads and trails, Swiss guides for mountain-climbers, excellent souvenir-views and pictorial postal-cards, and, above all, an amazing

volume and variety of maps and literature, both illustrative and instructive. Especially praiseworthy is the "annotated time-table," a handy pocket-volume, in which information as to the altitude, geographical and commercial relations, historic associations, etc., of each station is succinctly given, and blank leaves are interpolated for the record of the traveler's personal experiences and impressions. After making the journey with such a book, anybody could write a magazine-article, or lecture in public or private, with full confidence in his underlying facts, and consequent freedom of descriptive superstructure! The money-value of scenery has been exploited in Switzerland and Italy, but not everywhere upon our continent. This company appears to recognize it; and its liberal measures for the accommodation of tourists are already, as they deserve to be, a source of growing profit.

2. The second point emphasized by our rapid survey is the astonishing amount of business passing over this road. Already, in some places, four tracks have been put in; and a mere inspection of the numbers on the freight-cars shows that several hundred thousand of them are in use. Of course, the heaviest traffic is east of the mountains, in the immense and fertile wheat-growing region.

At Minneapolis, the party was entertained by two of its members, Messrs. George R. and F. W. Lyman, with a delightful trolley-ride through the city and park, and over to St. Paul.

At Chicago, Mr. and Mrs. Robert W. Hunt gave to their fellow-travelers a luncheon at the Auditorium-Annex, after which the party (diminished by the loss of many who had stopped at Minneapolis and Chicago) returned to the train, and proceeded without further extraordinary incident or accident to Philadelphia and New York, reaching the latter city on June 30th, a few minutes ahead of the schedule-time, and thus completing a memorable journey, by land and sea, of more than 10,000 miles, occupying 38 days, and achieved without a single disaster, disappointment, or serious discomfort to any person. Surely this must be deemed a conspicuous instance of the approval bestowed by Providence upon the wise and skilful arrangements of Man!

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OF

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